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PRAIRIE MOISTURE PROBLEMS:

CRAWL SPACE INVESTIGATIONS

IN NORWAY HOUSE, MANITOBA

Prepared for

Project Implementation Division
Policy, Research and Programs Sector
Canada Mortgage and Housing Corporation

by

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Toronto, Ontario

February 1987

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Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living conditions in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

Under Part V of this Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. CMHC therefore has a statutory responsibility to make widely available, information which may be useful in the improvement of housing and living conditions.

This publication is one of the many items of information published by CMHC with the assistance of federal funds.

DISCLAIMER

This study was conducted by The IBI Group for Canada Mortgage and Housing Corporation under Part V of the National Housing Act. The analysis, interpretations and recommendations are those of the consultants and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

CMHC SUMMARY

Background:

An unacceptable percentage of housing units in northern Prairie communities suffer from moisture related problems. Some researchers have proposed that one of the major sources of moisture may be damp crawl spaces caused by problem soil conditions and poor construction practices.

Objectives:

To implement and evaluate various crawl space remedial measures in order to assess their effectiveness in reducing moisture problems.

Methodology:

The Consultant investigated five moisture troubled houses in Norway House, Manitoba. Crawl space moisture sources were eliminated or reduced by sealing the crawl spaces from the foundation walls and surrounding subgrade. Air and wood moisture contents were monitored both before and after remedial measures were undertaken.

Conclusions:

The Consultant's findings did not indicate that high crawl space moisture levels had a significant impact on moisture problems in the living area of the house. However, there was considerable evidence of moisture-related deterioration in the crawl space itself.

The study exposed a number of "achilles' heels" and inherent contradictions in the current method of constructing crawl spaces in remote locations:

- the sill plate and header are difficult to insulate and seal, thereby becoming a major area for condensation and structural deterioration;
- reliance on a mechanical sump in conventional drainage strategies naively assumes proper maintenance in remote areas;
- the moisture barrier which is expected to isolate the crawl space from the ground can also hold water in the crawl space after flooding;
- the sand ballast used to protect the crawl space moisture barrier from damage can also act as a moisture source once dampened;
- opening vents in the spring to dry out the crawl space can actually increase crawl space moisture levels and condensation, since at this time outdoor air is quite moist and crawl space walls quite cold.

Recommendations:

The consultant has made several recommendations regarding both new construction and the retrofitting of existing units. The most satisfactory solutions would appear to be a raised dwelling with a heated crawl space at grade level or a post foundation with the crawl space left open.

SOLUTIONS TO MOISTURE PROBLEMS IN PRAIRIE DWELLINGS: INVESTIGATIONS AT NORWAY HOUSE, MANITOBA

ABSTRACT

Although damp conditions in the prairies are not as severe as those in the Atlantic provinces, prairie houses in remote small communities and rural areas have been troubled by moisture problems. Damage due to moisture can be a significant problem on the prairies. This study focused on the extent to which moisture sources in crawl spaces are causing damage in living areas and in crawl spaces themselves. It involved selecting five houses in Norway House, measuring existing moisture conditions, applying a range of moisture-reducing retrofit measures and monitoring their effects on air and wood moisture content.

The results suggest that moisture damage in the living area of the house is not directly caused by the moisture conditions in the crawl space. However, moisture can accumulate in wood members in the crawl space above the minimum levels which lead to deterioration.

To reduce or avoid this problem in new designs and in existing dwellings, it is recommended that crawl spaces be heated, insulated, provided with a floor sloped to a sump and an automatic sump pump, and that the floor be covered with heavy polyethylene film to serve as a vapour retarder. Protection for the floor can be provided by using wooden pallets or weak (self-leveling) concrete poured over the polyethylene. Particular attention should be paid to insulating and sealing the sill plate and header area. Insulation on the outside of the crawl space and living floor level can provide this protection more effectively than interior insulation. For new construction, the dwelling site should be well drained, the crawl space floor surface should be above the level of surrounding grade, and an impermeable sill gasket should be placed under the sill plates.

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SOLUTIONS TO MOISTURE PROBLEMS IN PRAIRIE DWELLINGS: INVESTIGATIONS AT NORWAY HOUSE, MANITOBA

This report summarizes the results of investigations and presents recommendations directed at reducing moisture problems in housing experiencing climatic conditions that can be found on the Canadian prairies.

We first discuss the problems and general solutions. We follow this by describing the specific scope and purpose of the investigation, the subject houses, retrofit solutions, and monitoring methods. We then present findings, conclusions and recommendations.

Appendices A to E inclusive describe the initial conditions, retrofit details, and observations for the Paupanekis, Tait, Laugher, Arthurson and Saunders houses, respectively. Appendix F provides retrofit details. Appendix G provides photographs of selected conditions.

PROBLEMS AND POSSIBLE SOLUTIONS

A variety of factors contributes to a range of dwelling moisture problems. It is thought that evaporation of subgrade moisture from the soil is an important contributor to moisture damage in the living area. A number of solutions are possible for dealing with that possible moisture source.

Factors Contributing to Moisture Problems

Houses built for low-income families in remote small communities and rural areas across Canada often have the disadvantage of being sited in locations with less than ideal drainage (a factor relating, in part, to low budgets for land acquisition). The soil under the dwellings may therefore contain high levels of moisture. In addition, these houses are built away from the mainstream of the Canadian house building industry, and consequently the available quality of workmanship is not as high as is found in urban areas to the south.

Other factors also contribute. These include high occupancy levels, heating in houses without chimneys (in some cases), and cooking and washing habits generating high levels of water vapour. In combination, all of these factors can lead directly to severe moisture problems. These problems make the house uncomfortable to live in, affect the appearance of the house both inside and out, and can significantly shorten the life of a dwelling due to deterioration of the structure (some houses may have a useful life of only five to ten years under severe conditions).

Problems Common to Moisture-Troubled Houses

High levels of moisture in the dwelling living area and in the crawl space may lead to:

- Mould and mildew on the interior surface of exterior walls, particularly at the junction of two walls, the walls and ceiling, and inside closets on exterior walls; and on objects stored in the crawl space and in closets on exterior walls.
- Lifting of sheet and tile floors.
- Rotting of wooden window frames.
- Deterioration of drywall around window frames.
- Deterioration of doors (particularly at the edges) due to moist air exfiltration, water condensation and the freeze/thaw cycle.
- Odour from mould and mildew.
- Deterioration of studs and floor joists due to rot.
- General uncomfortable feeling of dampness in the dwelling.

These problems result from warm moist air coming into contact with cold surfaces. These surfaces become thoroughly wetted by the resulting condensation and may not get an opportunity to dry out for long periods of time (if ever).

Soil as a Moisture Source

It is suspected that a major contribution to moisture in houses in remote small communities and rural areas on the prairies occurs from subgrade moisture evaporating from the soil, from the wicking action of moisture from the soil moving through the concrete walls and/or grade beams forming the crawl space, and from crawl space or basement flooding. Air movement also plays a role with regard to these moisture sources. For example, saturated air may enter the crawl space from subgrade sources (soil gas), or exterior air may pick up moisture from the crawl space on its way into the living space.

It has been assumed that evaporation from the soil is one of the main causes of moisture in the crawl space or basement and in the living area. It is therefore further assumed that solutions focusing on reducing moisture related to the crawl space or basement, should result in reduced damage not only in the lower level, but also in the living area. It is recognized that elements in the house such as the structure, the furniture, and other objects, may serve as sponges to absorb and release moisture under certain conditions.

Three Main Solutions

In dealing with crawl spaces, three approaches can be considered in reducing site/soil related moisture:

- Isolate the living area from the crawl space[1]: This will reduce moisture problems in the living area caused by moisture sources in the crawl space, but may not necessarily protect the sill plates, headers and floor joists from the high levels of moisture in the crawl

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1. An additional approach is to insulate the floor and leave the crawl space entirely open, thereby eliminating moisture build-up in a confined area.

space (and may even promote high levels of moisture content in these elements).

- o Isolate the crawl space from the surrounding soil: This measure will protect the crawl space and living area from moisture due to evaporation from the soil, and poor drainage. However, this approach does not prevent exfiltration of humid interior air to the area of the floor joists in the crawl space which may be at a significantly lower temperature than the living area.

Both of these approaches do not necessarily address the potential problem of sill plate, header and joist deterioration from wetting due to condensation. The third main approach combines aspects of the first two:

- o Adequately heat and isolate the crawl space from both the soil and the living area: This measure, if done as a means of preventing air infiltration from the living area to the area near the floor joists, can be useful in those houses where both site conditions and occupancy levels are particularly conducive to crawl space moisture. The result should be greatly reduced moisture levels in the crawl space.

These solutions are considered for the specific dwellings discussed below.

OBJECTIVES AND SCOPE OF THE INVESTIGATIONS

The objective of the investigations was to test alternative methods for reducing moisture in specific houses considered to be representative of those commonly built in remote small communities and rural areas, often under various forms of government assistance. The ultimate goal of the project was to develop and demonstrate construction and retrofit techniques that will reduce moisture damage and prolong dwelling life.

The scope of the investigation required a focus on specific aspects:

- o prairie houses: to use existing dwellings at Norway House, Manitoba, a location considered by CMHC to be representative of central/northern prairie climate and site conditions.

- o moisture reduction: to measure how moisture can be reduced and comfort and durability improved, with energy conservation treated as secondary in importance.

- o crawl spaces: to examine dwellings with crawl spaces as opposed to those with full basements.

- o low cost construction solutions: to demonstrate the ability of simple low cost measures to reduce moisture, with the intent that these measures can be applied in new and retrofit situations and confined crawl spaces (aspects of lifestyle activities in the living space of the dwellings were to be noted, but were not to form part of the remedial recommendations).

- o six months of monitoring: to take into account the project start in mid-winter with the need for results early by the following autumn.

In addition to the above factors and conditions, the solutions were to be applied in winter, thereby limiting certain possibilities such as installing a protective cover of sand or fine gravel over a vapour retarder on the crawl space floors, and sealing damp headers, sill plates and adjacent portions of floor joists.

HOUSES SELECTED AND RETROFIT APPROACHES

Five dwellings were selected for the study from a limited number suggested by CMHC. Criteria for selection included the variety of potential moisture sources and suitability in terms of crawl space use, occupant attitudes toward the project and dwelling maintenance in general, and overall condition of the dwellings (some candidate dwellings were in such serious disrepair that leakage through upper portions of the building envelope could effect temperature and moisture readings).

The five selected dwellings are located in Norway House, Manitoba (see Exhibit 1). The dwellings selected are all bungalows having a main floor area of 90 to 100 m^2. Ages range from two to seven years. All have insulated crawl space walls. Other characteristics and the retrofit approaches used vary as indicated below. These differences all have an impact on the study findings.

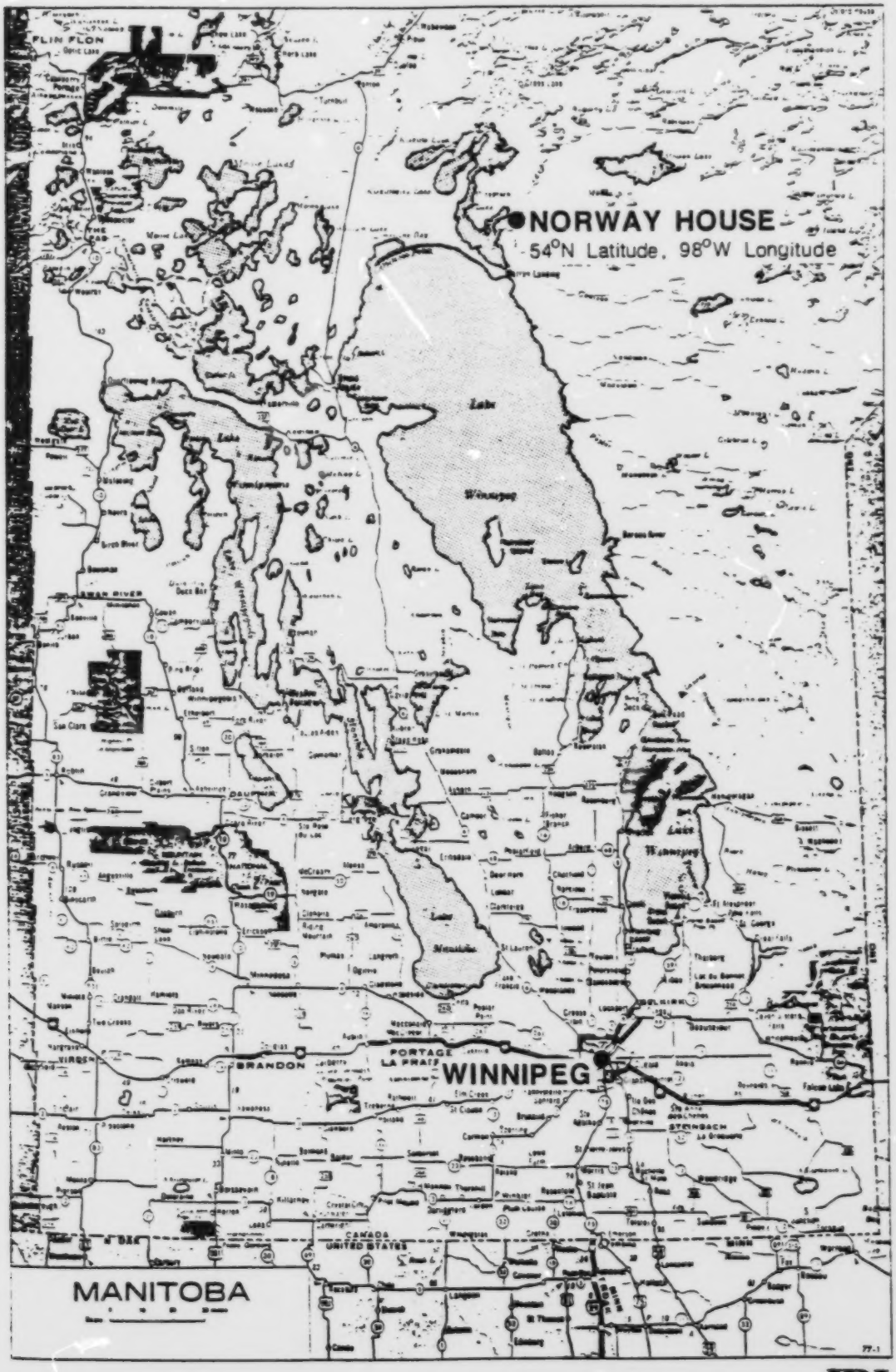
Paupanekis House

This dwelling serves as the base case. Its characteristics are as follows:

- age - two years;
- occupancy - four adults;
- preserved wood foundation, insulation RSI 3.5 in wall;
- sill plate and headers insulated, but not sealed;
- good site drainage, internal and external weeping tile;
- polyethylene on crawl space floor covered with 100 mm coarse sand and fine gravel (serving to act as a potential moisture source);
- crawl space heated directly by forced air furnace (also serving the living area) and by heating duct radiation;
- crawl space vents were open (and remained open all winter).

As this house served as the base case, there was no retrofit work carried out. This house was significantly different than the other houses in that it had forced air heating and open crawl space vents. See Appendix A for more details.

EXHIBIT 1 LOCATION OF NORWAY HOUSE, MANITOBA



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Tait House

This dwelling is similar to the Paupanekis house in terms of crawl space construction. Its characteristics are as follows:

- o age - two years;
- o occupancy - two adults, two children;
- o preserved wood foundations, insulation RSI 3.5 in wall;
- o sill plates and headers insulated, but not sealed;
- o good site drainage, internal and external weeping tile (but subsoil drainage was not good);
- o polyethylene on crawl space floor covered with 100 mm coarse sand and fine gravel (serving to act as a potential moisture source);
- o crawl space heated directly by forced air furnace (also serving the living area) and by heating duct radiation;
- o crawl space vents were plugged by means of batt insulation;
- o the floor sheathing under the vestibule was dripping wet;
- o efflorescence on the inside top of the footings.

The retrofit objective in this dwelling was to check the importance of covering the crawl space and footings with a vapour retarder. See Appendix B for more details.

Laugher House

The characteristics of this house are as follows:

- o age - seven years;
- o occupancy - two adults, three children;

- o living area heated by electric baseboard heaters;
- o concrete foundation insulated with 50 mm type 2 expanded polystyrene;
- o headers insulated with RSI 3.5 glass fibre batts;
- o site drainage demonstrated extensive flooding at the spring thaw;
- o crawl space vents were closed all winter, but the vent doors were not insulated;
- o polyethylene film on crawl space, did not adequately cover the footings, and was degraded in many places;
- o an electric baseboard heater was present in the crawl space;
- o significant build-up of frost on the sill plate;
- o glass fibre batt insulation was frozen to the headers.

The retrofit objective was to separate the crawl space from the soil by replacing the polyethylene film and by adding polyethylene to the foundation walls. See Appendix C for more details.

Arthurson House

The characteristics of this house are as follows:

- o age - six years;
- o occupancy - six adults, three children;
- o living area heated by electric baseboard heaters;
- o concrete foundation walls insulted with 50 mm type 2 expanded polystyrene;
- o headers insulated with 64 mm extruded polystyrene;
- o good site drainage;
- o polyethylene film on crawl space covered with a thin layer of gravel;

- o electric baseboard heater for the crawl space was not plugged in;
- o crawl space vents were plugged with insulation;
- o polyethylene film on the crawl space floor surface had many punctures;
- o sheet goods flooring in the livingroom was worn through in several places.

The retrofit objective was to test the effect of isolating the crawl space by sealing it off from the soil and from the living area above. See Appendix D for more details.

Saunders House

The characteristics of this house are as follows:

- o age - seven years;
- o occupancy - two adults, three children;
- o living area heated by electric baseboard heaters;
- o concrete foundation walls were insulated with 50 mm type 2 expanded polystyrene;
- o batt insulation had been removed from the headers;
- o electric baseboard heater for the crawl space was not plugged in;
- o crawl space vents were boarded up but not sealed or insulated;
- o site drainage very poor;
- o polyethylene on crawl space floor was covered with a layer of sand and partially rolled back in places to allow a trench to be dug to encourage drainage to the sump;
- o headers and joists near the headers were thoroughly wet;

- o periodic flooding occurs.

The retrofit objective, given the tendency for the crawl space to be flooded at spring thaw and during rains, was to demonstrate the ability of the living room floor to serve as a moisture retarder. See Appendix E for more details.

RETROFIT

The retrofit was carried out by Manitoba Metis Housing Development Inc. using local labour. Members of the consulting team explored conditions at each dwelling prior to retrofit with the construction supervisor and carried out site inspection prior to approving the completion of the retrofit contract. Exhibit 2 provides a breakdown of costs for the retrofit work.

Generally the retrofit included sealing the floor to act as a barrier to air movement. This would have the effect of lowering the neutral pressure plane under conditions when outside air would enter the crawl space due to wind. See Exhibit F for retrofit details.

MONITORING METHODS AND FREQUENCY

Monitoring took place before and after retrofit. The monitoring consisted mainly of air temperature and relative humidity readings, floor surface temperature readings, and wood moisture readings. Observations were made concerning any changes in lifestyle and occupancy during the monitoring period, and when heavy rains took place. The dwellings were visited two to three times per week to check and move monitoring equipment and to note any occupancy or site conditions that would affect moisture accumulation.

EXHIBIT 2

COST ANALYSES[1]

CRAWL SPACE RETROFITS - NORWAY HOUSE

	TAIT HOUSE	LAUGHER HOUSE	ARTHURSON HOUSE	SAUNDERS HOUSE	TOTAL
Materials and Freight	$ 358.80	$ 358.77	$1,223.29	$ 358.77	
Labour and Employee Benefits	397.00	396.98	1,000.36	396.98	
Supervision	640.00	640.00	640.00	640.00	
Board, Lodging and Travel	398.35	398.35	398.35	398.35	
Total (less profit)	$1,794.15	$1,794.10	$3,262.00	$1,794.10	$8,644.35
Profit	$ 25.85	$ 125.90	$ 384.00	$ 395.90	$ 931.65
TOTAL CONTRACT PRICE	$1,820.00	$1,920.00	$3,646.00	$2,190.00	$9,576.00

1. As provided by Mr. E. Semeniuk, Construction Supervisor, Manitoba Metis Housing Development Inc.

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Air Temperature and Relative Humidity

Outdoor air temperature and relative humidity readings were taken from the Norway House Weather Station which records this information continuously. Within the houses monitoring was characterized as follows:

- o six Honeywell Model 612 hygrothermographs with seven day wind up were used;
- o two hygrothermographs alternated between the Tait and Paupanekis houses;
- o two hygrothermographs alternated between the Laugher, Saunders and Arthurson houses until late March, after which time two additional hygrothermographs were installed for continuous readings in the Arthurson house, allowing the other two to be alternated between the Laugher and Saunders houses.
- o in each house one hygrothermograph was installed in the crawl space and one was installed in a bedroom or in the utility room;
- o recording was continuous in each case for a period of three days or one week (and in one house continuously over the entire monitoring period);

This information was used to compute air moisture content, i.e. the weight of moisture per unit weight of dry air.

Floor Surface Temperature

This information was collected using a Taylor Model 9200K digital thermocouple thermometer with 9202-K surface temperature probe. Four temperatures were taken each time the home was entered to relocate or change charts on the hygrothermograph (approximately once per week starting in late February). One reading was taken in each room.

Wood Moisture Content

This information was collected using a Delmhorst Model G-30 wood moisture detector equipped with dual insulated pin probes. Readings were taken four times from January through July (approximately every two months). Generally the readings were taken at the sill plate and in the floor sheathing near the headers. In those houses with preserved wood foundations, readings were taken near the base of the wall and approximately 150-200 mm above the footings.

All monitoring took place over a six month period, from mid-January to mid-July 1986. See Exhibit 3 for the monitoring schedule.

FINDINGS

The overall findings are briefly summarized by house. Extensive detail is provided in the various appendices relating to each house.

Paupanekis House

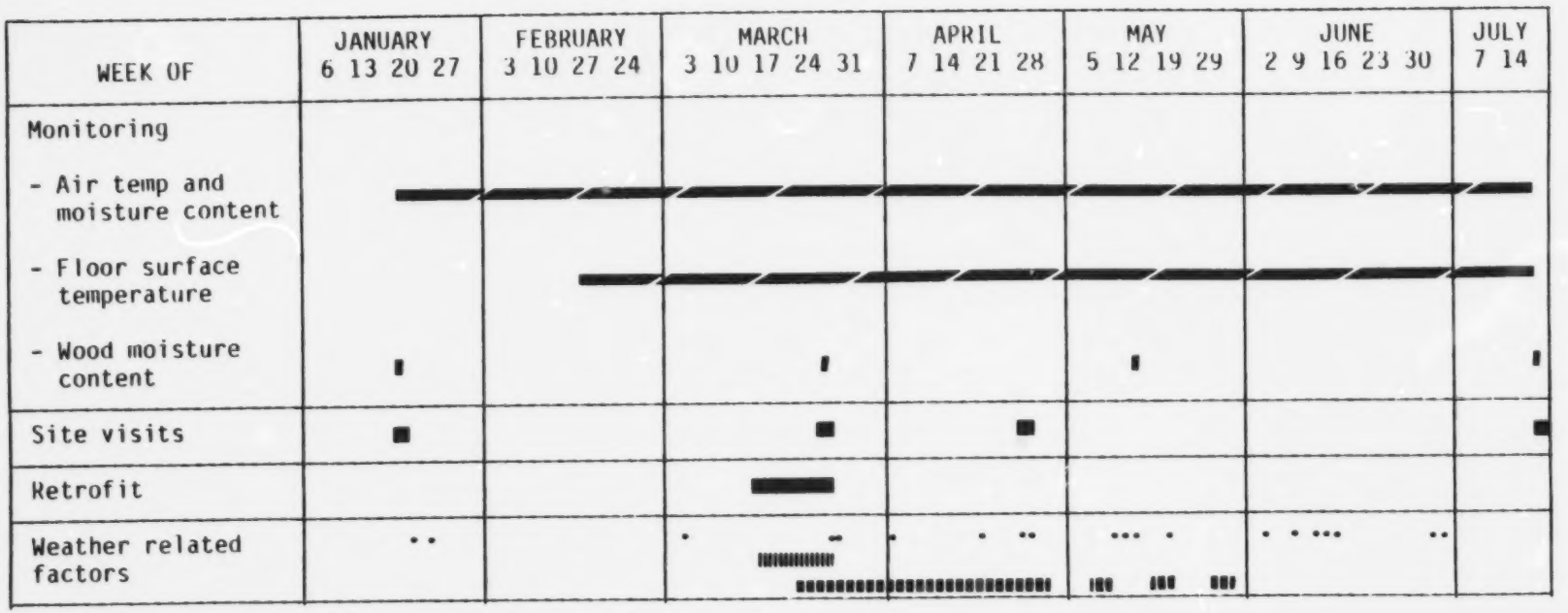
- o Temperature: The crawl space air temperature remained similar to that of the living space (because both spaces were heated by the forced air furnace), until auxiliary heating was needed less frequently as the weather warmed up.

- o Air Moisture Content: The crawl space air moisture content was similar to that of the living space. When the furnace began to be used intermittently the air moisture content in both locations increased slightly as the moisture content of the outdoor air increased (the crawl space vents were open throughout the winter at this house). In June and July relative humidity readings in the crawl space were in the 80-90% range.

- o Crawl Space Wood Moisture Content: The base of the preserved wood foundation wall showed increasing wood moisture content over the monitoring period, in excess of 20%. Higher up the foundation wall the moisture content was lower. Some readings decrease from January

EXHIBIT 3

PROJECT SCHEDULE



• • • - high winds > 30 knots
▮▮▮▮▮▮▮▮ - early thaw
▪▪▪▪▪▪ - flooding

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to March, but generally readings increase during May and July.

- o Floor Surface Temperature in the Living Area: The readings were generally constant in the range of 20°C.

Tait House

- o Temperature: Crawl space air temperature remained very close to that of the living space, until the crawl space vents were opened and the use of the forced air furnace became intermittent (as the weather warmed up).

- o Air Moisture Content: Crawl space air moisture content was higher than that of the living space air until retrofit was completed. Then the crawl space air moisture content dropped significantly, the living area moisture content decreased slightly. There continued to be a divergence in the values for these variables. When the vents were opened towards the end of April, the air moisture content dropped slightly in both the crawl space and living area. The relative humidity of crawl space air was in the range of 60-80% in June and July.

- o Crawl Space Wood Moisture Content: Lower portions of the preserved wood foundation wall were saturated at the start of monitoring. Further readings, after retrofit, could not be taken at these points due to the placement of the moisture retarder. Generally all readings increased from January to March. There was some decrease in the moisture content readings after March. Nearly all readings were higher in July than in January.

- o Floor Surface Temperature in the Living Area: These readings were generally 20°C or slightly greater.

Laugher House

- o Temperature: The crawl space air temperature remained close to 10°C until the outdoor air temperature began to increase in late spring. The living area air temperature remained constant at about 23-25°C on average.

- o Air Moisture Content: The crawl space air moisture content was lower than that of the living area air.

However, it began to rise at spring thaw. This coincided with extensive flooding in the crawl space (the sump pump was not working initially). Despite this, the crawl space air moisture content remained considerably lower than that of the living area air, although the relative humidity of the crawl space air was close to saturation in late April and early May. In June and July the relative humidity was 65-85%.

- o Crawl Space Wood Moisture Content: The sill plate remained saturated throughout the monitoring period, except for two locations. The floor sheathing showed some decrease in moisture content in late-winter, but nearly all locations had a higher moisture content in July than in January. All of these locations have levels of wood moisture which exceed the safe limit of 20% (beyond which wood becomes susceptible to rot or decay at the temperature range found in the crawl space).

- o Floor Surface Temperature in the Living Area: These temperatures range from 15-21°C. Note that the living area air temperature was generally cooler than that of most of the other houses being monitored.

Arthurson House

- o Temperature: The crawl space air temperature was consistently lower than that of the living area air.

- o Crawl Space Air Moisture Content: The crawl space air moisture content was consistently lower than that of the living space air. It gradually rose as the crawl space was ventilated and as the moisture content in the outdoor air increased in the spring. Retrofit appeared to have no impact on crawl space air moisture content or on that of the living area.

- o Crawl Space Wood Moisture Content: Floor sheathing moisture content generally increased between June and July. The sill plate moisture content generally increased steadily from January to July. In all cases wood moisture content is under 20%. The March and/or April readings show a slight decrease.

- o Floor Surface Temperatures in the Living Area: Readings for these values ranged between 19-22°C.

Saunders House

- o Temperature: This house had high living space air temperatures (around 25°C), but the crawl space temperature was similar to that of the other houses having electrical baseboard space heating.

- o Air Moisture Content: Saunders house had the highest living area and crawl space air moisture content. This was primarily due to the poorly graded site and related crawl space flooding. Relative humidity of crawl space air generally ranged from 80-95% or more in June and July.

- o Crawl Space Wood Moisture Content: Floor sheathing was dripping wet. Most joists had some readings over 20%. Although the readings gradually decreased slightly over the monitoring period, nearly all were still over 20% in July.

- o Floor Surface Temperatures in the Living Area: This house consistently had the lowest floor surface temperature readings combined with the highest living area air moisture content. The occupants continually reported floor surface condensation. Temperatures of the floor surface were in the range of 16-22°C with no readings above 24°C.

SPECIFIC CONCLUSIONS

We draw the following conclusions related to each house:

- o The Paupanekis house, serving as a base case, experienced higher crawl space air moisture content than the Tait house after retrofit. This can be explained, in part, by the fact that the sand serving to protect the vapour retarder served as a moisture source. This moisture in turn came from water forced up through discontinuities in the vapour retarder and possibly from absorbing condensation in summer from damp outdoor air entering the cool crawl space. The result was reduction in summer drying of sill plates, headers, joists and floor sheathing.

- The Tait house, because of its similarity to the Paupanekis house provides an interesting comparison relating to retrofit. Before retrofit the crawl space and living area air moisture content was higher than that of the Paupanekis house. This is probably due to the presence of children in the Tait house (there were no children living at the Paupanekis house). However the sand/gravel floor in the crawl space also contributed to moisture content, because subsoil drainage was also a problem in this house. The crawl space under the uninsulated vestibule was also a moisture source, due to condensation dripping through the floor. Application of the vapour retarder to the floor of the crawl space and to close off the area under the vestibule in the Tait house appears to be the primary cause of the reduced air moisture content in that location.

- The Laugher house appeared to experience no impact due to retrofit. It had a significant crawl space moisture source consisting of a depression in the crawl space floor which held standing water. Even when this depression was filled during retrofit, spring flooding and later rains, as well as condensation of moist outdoor air in the cool crawl space contributed to the high wood moisture content readings in the sill plate, headers and in edge of floor sheathing. The extensive moisture content in header and nearby surfaces is largely due to the fact that the temperature of the inner surface of the headers was often only slightly above and sometimes below the dew point of the crawl space air. In early spring infiltration of moist outdoor air at the sill plate created added moisture when it came into contact with cool crawl space air below the dew point of the outside air.

- Although the Arthurson house was reported to have serious moisture problems in the living area, it maintained continual drying of the sill plates and headers into the summer because a) the crawl space was not connected to the living area with its high occupancy, and b) because the house is located on a high, well-drained site. The dew point of the crawl space air in early spring and summer was always below that of the computed header inner surface temperature.

- The Saunders house experienced no retrofit impact on the crawl space air moisture content due to early spring thaw flooding. The living area floor surface condensation was due to high internal temperatures and high relative humidity combined with drops in temperature overnight in the living area and crawl space. The

extremely poor site conditions likely created a highly humid micro-climate in the immediate vicinity of the house in early spring and summer. The computed value of the header temperature indicated nearly continuous values either below the crawl space air dew point or within 1-2 degrees above the dew point.

GENERAL CONCLUSIONS

The rationale for this investigation was based on the premise that moisture sources in the crawl space contribute directly to elevating moisture levels and to causing damage in the living area. Although the observed sample was small, in general, we conclude that this is not likely to occur, given the range of conditions observed in the dwellings at Norway House.

Our general conclusions are as follows:

1. If the crawl space is heated, insulated, and the soil covered with a vapour retarder, it is unlikely that moisture sources in this area can contribute to moisture in the living area. The reason for this is that the crawl space air moisture content appears to be equal to or less than that in the living area. The main methods whereby moisture can be transferred from the crawl space to the living area therefore do not act. These methods and why they do not act can be explained as follows:

   a) the vapour pressure in the crawl space does not exceed that in the living area, therefore there is no driving force to cause diffusion through the floor plane from the crawl space to the living area;

   b) movement of cooler crawl space air to the living area is not likely to occur except by means of mechanical ventilation (such as provided by the forced air of electric furnaces used in the Paupanekis and Tait houses, or by living area exhaust fans which create negative pressure, drawing air from the crawl space). In any event, displacement of living area air by crawl space air

with its lower moisture content cannot increase moisture in the living area (unless this displacement is caused by exterior air moving through the crawl space into the living area; in that case it will be picking up moisture thereby having its drying potential reduced); and

c) wicking action in foundation walls will not effectively move moisture from the soil into the living area of the dwelling because construction details at the sill plate, header and floor sheathing make this form of moisture transfer difficult.

The extensive use of plywood floor sheathing and sheet goods floor finish will further inhibit moisture diffusion and air movement between the living area and crawl space.

2. A layer of sand or fine gravel for protecting the vapour retarder used to cover the crawl space floor may serve as a moisture source if subsoil drainage is poor, or if the sand or gravel becomes wet from flooding.

3. Infiltration of outside air at the sill plate and lack of insulation on headers is contributing to moisture build-up in sill plates, headers, floor sheathing and joists near the headers. Moisture damage to sill plate, headers, and the edge of floor sheathing at the header is likely if these areas are not sealed and insulated on the outside.

4. Another potential moisture source with respect to sill plates, headers and joists, is soil moisture transmitted by wicking action through concrete foundation walls. None of the houses in the study employed a membrane to provide an impermeable seal between the top of the concrete foundation wall and the underside of the sill plate. In fact, the concrete foundation walls may serve as a sponge to transfer soil moisture to the crawl space.

5. Houses in poorly drained areas did not exhibit any significant drying out of the crawl space structure in summer, in part because of the occurrence of condensation of warm moisture on cool building elements in the crawl space. In addition, on certain days in late May/early July, moist outdoor air infiltrating the crawl space at the sill plate will cause condensation because the dew point of this air is above the temperature of the cool crawl space air.

6. Heating the crawl space will help maintain a more comfortable floor, reduce the possibility of floor surface condensation, reduce the possibility of condensation on floor joists because of inevitable cracks and gaps that would occur in a vapour barrier on the warm side of insulation placed in floor joists, and will provide an important opportunity for heated storage. Cool crawl space temperatures increase relative humidity which in turn increases the moisture content of exposed wood.

7. A sealed crawl space floor sloped to a sump equipped with a automatic pump controlled by switches near the bottom of the sump, can help prevent moisture build-up due to flooding in a heated crawl space. However, residents must insure that the sump pump is operable at all times.

8. Having the crawl space floor at a level higher than the outside grade can reduce the likelihood of crawl space flooding.

It follows from the above that a) if air from the living area with its relatively high levels of moisture enters the crawl space (due to wind pressure, mechanical ventilation, and/or diffusion), and b) if the crawl space is not sufficiently heated, then damage to crawl space elements could occur. These elements, such as sill plates, headers and adjacent portion of floor joists and floor sheathing are susceptible to moisture damage from high relative humidity in the crawl space from whatever source. Measures can be taken in new construction and in retrofit of existing houses to reduce the likelihood of this happening.

The measures used in the study created an air barrier in the crawl space (i.e., functioned as "air sealing") to reduce air movement, the dominant form of moisture transport.

RECOMMENDATIONS

We therefore suggest a range of steps to enable crawl spaces to be sealed off from the soil and adjacent site.

It should be noted that the various differences among the test houses with respect to heating systems, occupancy, site conditions, crawl space venting, etc. affect the results.

New Construction

1. Wherever possible, selected well drained sites. Design the floor elevations so that the crawl space floor is above the level of the immediate surrounding grade. Provide at least 1,000 to 1,100 mm clearance between the crawl space floor and the underside of joists to facilitate crawl space maintenance and storage of small or medium sized items.

2. Reduce potential for moisture transmission through foundation walls. To eliminate wicking action, footings should be poured on a heavy vapour retarder. A similar material should be used between the top of the foundation wall and the sill plate, combined with a gasket to eliminate air infiltration (item 4 below). Use insulation (item 4 below) either on the outside or on the inside of the foundation wall to prevent moisture from either entering the foundation wall and/or preventing it from entering the crawl space. This air sealing is important because moisture transport is influenced far more by air movement than by diffusion.

3. Heat the crawl space. This alternative is to be preferred over that of insulating the floor, because heating the crawl space:

   a) provides a more comfortable floor and reduces the possibility of floor surface condensation;

   b) avoids the difficulty of providing an air barrier at the floor, and potential problems of interstitial condensation within the floor;

   c) enables the crawl space to be used for convenient winter storage; and

   d) lowers the relative humidity in the crawl space.

   Heating could be done in variety of ways:

   o electric baseboard heaters in the crawl space and living area;

- o oil or wood stove on a grille connecting the crawl space and living area and with cold air return grilles along the perimeter of the floor of the living area (living area walls must be well insulated);

- o forced air furnace (a down-flow type located in the living area for ease of maintenance) using the insulated crawl space as a plenum provided with warm air grilles along the floor perimeter of the living area[2];

4. Adequately insulate and seal the crawl space foundation walls. This should be done to prevent the opportunity for moisture build-up on cold surfaces. Apply rigid insulation to the exterior of the foundation walls up to the level of the living area floor. Protect the insulation from mechanical damage by means of pressure-treated plywood,[3] or use parging. This is the most efficient means of insulating and sealing the entire foundation wall. An alternative is to apply insulation on the inside (50 mm of expanded polystyrene on the foundation wall and over the top of the footing, at the sill, and at the headers, all sealed with accoustical sealant). However, this solution is very difficult to ensure effective air sealing at the headers.

5. Encourage rapid drainage in the crawl space. The crawl space floor should be sloped to a sump containing an electric pump activated by a control device sensitive to water build-up at the base of the sump pit (however, the mechanical reliability of such devices in remote areas where repair skills may be hard to find, suggests that other techniques such as a dry sump should be considered). Apply a 10-12 mil polyethylene film in large sheets, with sealed joints to serve as a vapour retarder on the floor of the crawl space. The floor of the crawl space should be prepared to accept the polyethylene film by providing a smooth slope to the

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2. However, this solution may have negative impacts: the mechanical solution may not be reliable or easily repaired in remote small communities and rural areas, and unpreventable flooding in the crawl space may provide a powerful moisture source which could affect the entire dwelling. This solution also runs the risk of back drafting combustion appliances if the crawl space is leaky.

3. Use of preserved wood foundations should be accompanied by careful footing design, given the saturation problems noticed at the base of the foundation walls in the Tait and Paupanekis houses.

sump pit. Provide protection against mechanical damage for this vapour retarder by supplying wood pallets to serve as a platform for objects stored in the crawl space, or use weak (self-leveling) concrete poured over the polyethylene.

6. Provide for ventilation in the crawl space. Ensure that adequately sized crawl space vents, complete with insulated doors, are located on all sides of the crawl space. The vents should be closed in the early fall until early summer (when the foundation wall is sufficiently warm so as to prevent condensation of vapour in outside air entering the crawl space and contacting the wall surface. The vents should then be opened to enable as much air circulation as possible during the summer. An alternative, if a forced air furnace is used to heat the crawl space and living area, is to run the fan during the summer with the crawl space vents closed.

7. Educate homeowners in the use and maintenance of the crawl space. Homeowners should be reminded to do the following:

   - ensure that insulation is maintained on the crawl space walls and that this insulation is sealed so that crawl space air will not condense on or in the crawl space wall system;
   - ensure that the crawl space is heated to at least 15°C during the winter and preferably to the same temperature as the living area;
   - take care not to puncture the polyethylene film serving as a vapour retarder, and use wood pallets for storage of heavy items in the crawl space.
   - test the operation of the sump pump regularly;
   - ensure that the crawl space vents are open in early summer and closed in the fall or, if a forced air furnace is provided, keep the vents closed and run the fan during the summer.

Existing Houses

Measures for reducing the potential for moisture problems in existing houses are similar to those for new designs. The critical differences relate to limitations on site selection, crawl space design and sill plate/foundation wall detail.

1. Modify the site if possible to ensure that drainage is away from crawl space walls. Reducing crawl space flooding is one of the first measures that should be considered in attempting to eliminate moisture problems existing in houses. This may require sloping the ground in the immediate vicinity of the foundation walls, down and away from the house to eliminate ponding of rain and melting snow against the crawl space walls. Other modifications to the site surface may be required to ensure that run-off from adjacent properties does not reach the area immediately adjacent to the house.

2. Apply vapour retarder to inside of crawl space walls. Because the foundation walls are likely in direct contact with the soil through the footings, the inside face of the wall should be sealed off from the crawl space. This will reduce "wicking" as a moisture source.

3. Heat the crawl space. A variety of methods can be used to heat the crawl space:

   - o electric baseboard heaters with fan;
   - o oil or wood stove on a grille connecting the crawl space and living area, and with cold air return grilles along the perimeter of the floor in the living area (living area walls must be well insulated).

   Using a forced air furnace with the insulated crawl space acting as a plenum is not recommended if there is any possibility of flooding in the crawl space.

4. Adequately insulate and seal the crawl space walls. Insulating the walls will prevent the opportunity for moisture build-up on cold surfaces. It will also enable economic heating of the crawl space, providing for a more comfortable living area floor, enabling more convenient access to the crawl space for storage of items in winter, and, most importantly, enabling the air in the crawl space to carry a greater absolute amount of moisture. Sealing the crawl space walls will prevent condensation of vapour in interior crawl space air as it comes in contact with infiltrating cold air, particularly at the sill plate and top of the foundation wall. The most effective way to insulate is the application of rigid insulation to the exterior of the foundation wall up to the living area of the floor. This insulation should be protected from mechanical

damage from means of pressure treated plywood or parging. The joint between the top of the foundation and the sill plate should be caulked.

5. Encourage rapid drainage in the crawl space. The floor of the crawl space should be smoothly sloped to a sump pit. A sump pump or dry sump pit should be used to control water build-up in the event of flooding.

6. Provide for ventilation in the crawl space. Ensure that adequately sized crawl space vents, complete with insulated doors, are located on all sides of the crawl space. Unless the crawl space has experienced flooding in the fall and has not had a chance to dry out, the vents should be closed in the early fall until early summer (when the foundation wall is sufficiently warm so as to prevent condensation of vapour and outside air as it contacts the wall surface). The vents should then be open to enable as much air circulation as possible during the summer.

7. Educate homeowners in the use and maintenance of the crawl space. Homeowners should be interviewed to determine what experience they have had concerning crawl space problems and to determine the extent that they understand the causes of these problems. They should be reminded to do the following:

   - install insulation and maintain this in good condition and insure that the crawl space walls are sealed so that crawl space air will not condense on or in the crawl space wall system;
   - ensure that equipment is installed to heat the crawl space to about 15°C during the winter, or preferably to the same temperature as the living area;
   - use wood pallets for storage of heavy items on the crawl space floor so as not to puncture the polyethylene film serving as a vapour retarder on that surface;
   - if a sump pump is installed, its operation should be tested regularly;
   - ensure that the crawl space vents are open in early summer and closed in the fall or, if a forced air furnace is used to heat the crawl space as well as the living area, keep the vents closed all year and run the fan during the summer.

* * * * * *

We recognize that several of these recommendations tend to overlap in terms of their effects in preventing moisture build-up and condensation within the crawl space. We believe this apparent duplication is necessary because no one single solution can be relied upon to be effective over time under conditions of dwelling use and climate in remote small communities and rural areas.

APPENDIX A: PAUPANEKIS HOUSE

Crawl Space Features

Air Moisture Content and Temperature Data Charts

Floor Surface Temperature Readings

Wood Moisture Content Readings

CRAWL SPACE FEATURES

PAUPANEKIS HOUSE

OCCUPANCY: 4 adults, 0 children

DWELLING CHARACTERISTICS:

- age: 2 years;
- type: bungalow;
- dimensions: 12.2 x 7.4 m;
- gross floor area: 90.3 m^2 (includes base of exterior wall).

CRAWL SPACE FEATURES (before retrofit):

- preserved wood foundation (PWF);
- clearance height: 1120 mm with extensive heating ducts;
- insulation: sandwiched within wall - RSI 3.5 glass batt;
- site drainage: very good, weeping tile internal and external to footing;
- polyethylene on crawl space floor covered with 100 mm gravel;
- soil: generally dry, visible moisture in soil around footing;
- heating: direct forced air, indirectly by heating duct radiation;
- vents: kept open;
- truss joists;
- extensive efflorescence on footing.

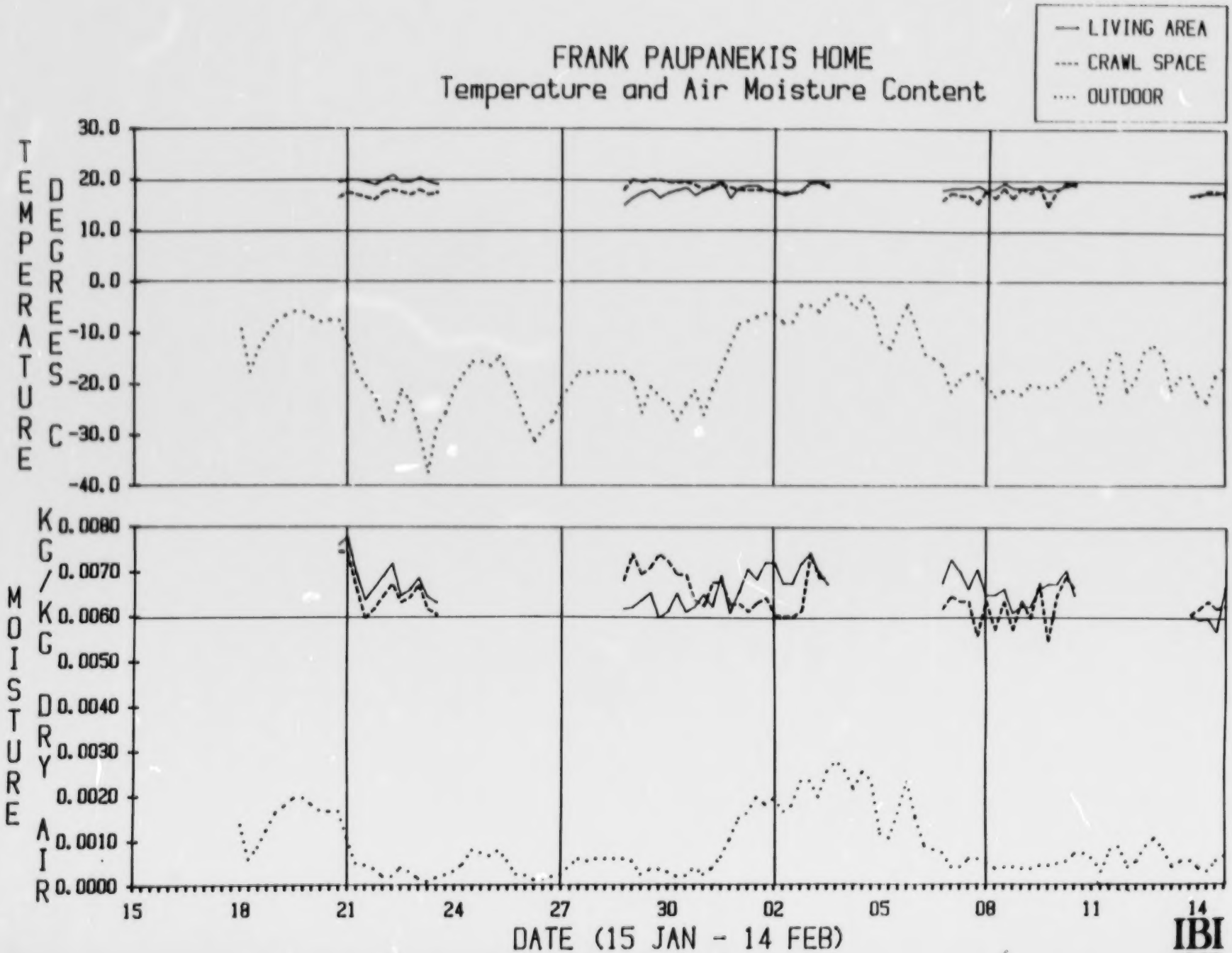
CRAWL SPACE OBSERVED PROBLEMS:

- the moisture levels in the corners were significantly lower than in the Tait House with PWF;
- the vestibule floor sheathing surface was dry.

RETROFIT OBJECTIVE:

To be monitored as base case house; therefore no retrofit.

AIR MOISTURE CONTENT AND TEMPERATURE DATA CHARTS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Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
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-20.0
-30.0
-40.0
MOISTURE KG/KG DRY AIR
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DATE (15 JAN - 14 FEB)
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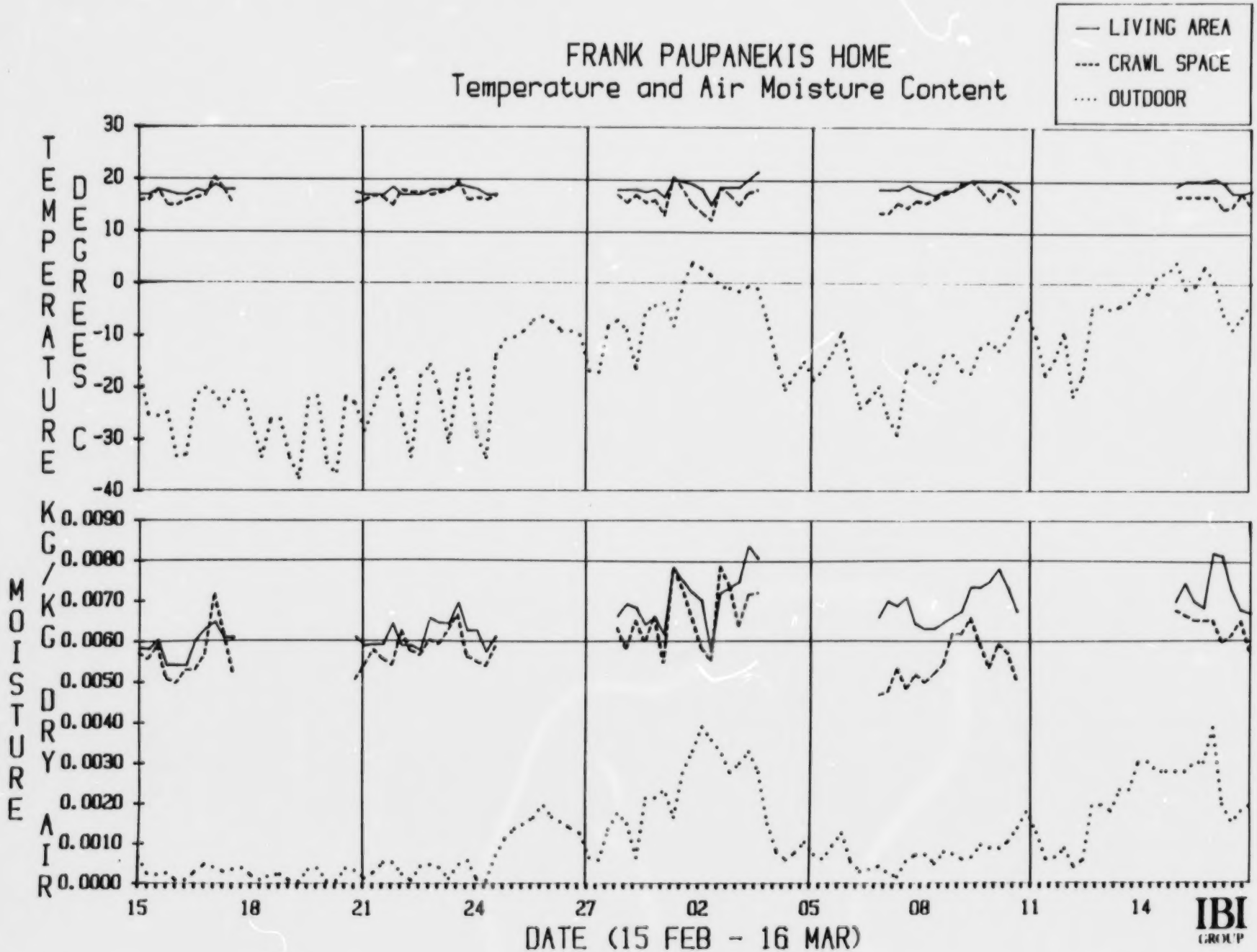
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— LIVING AREA
---- CRAWL SPACE
.... OUTDOOR
TEMPERATURE DEGREES C
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MOISTURE KG/KG DRY AIR
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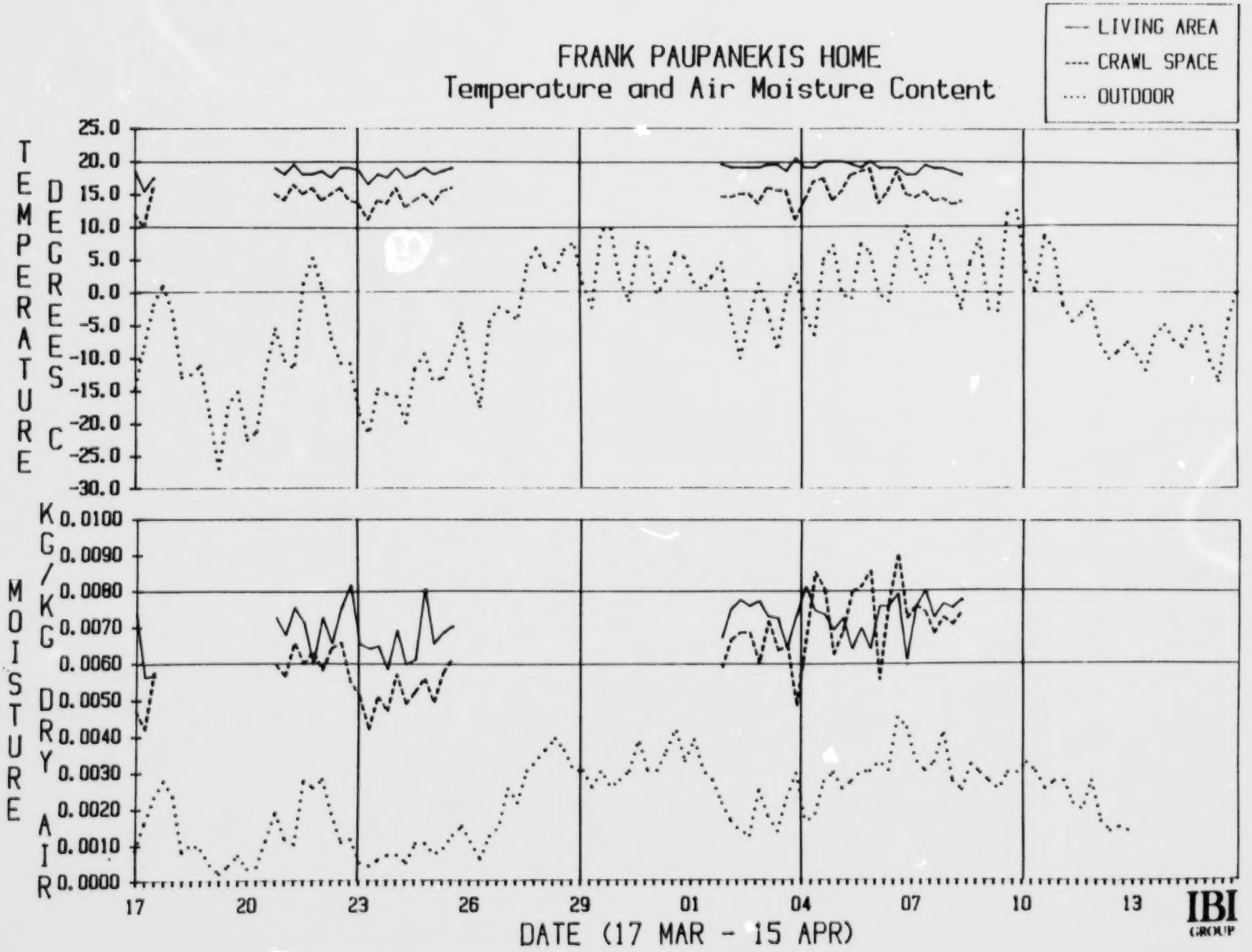
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MOISTURE AIR KG/KG DRY
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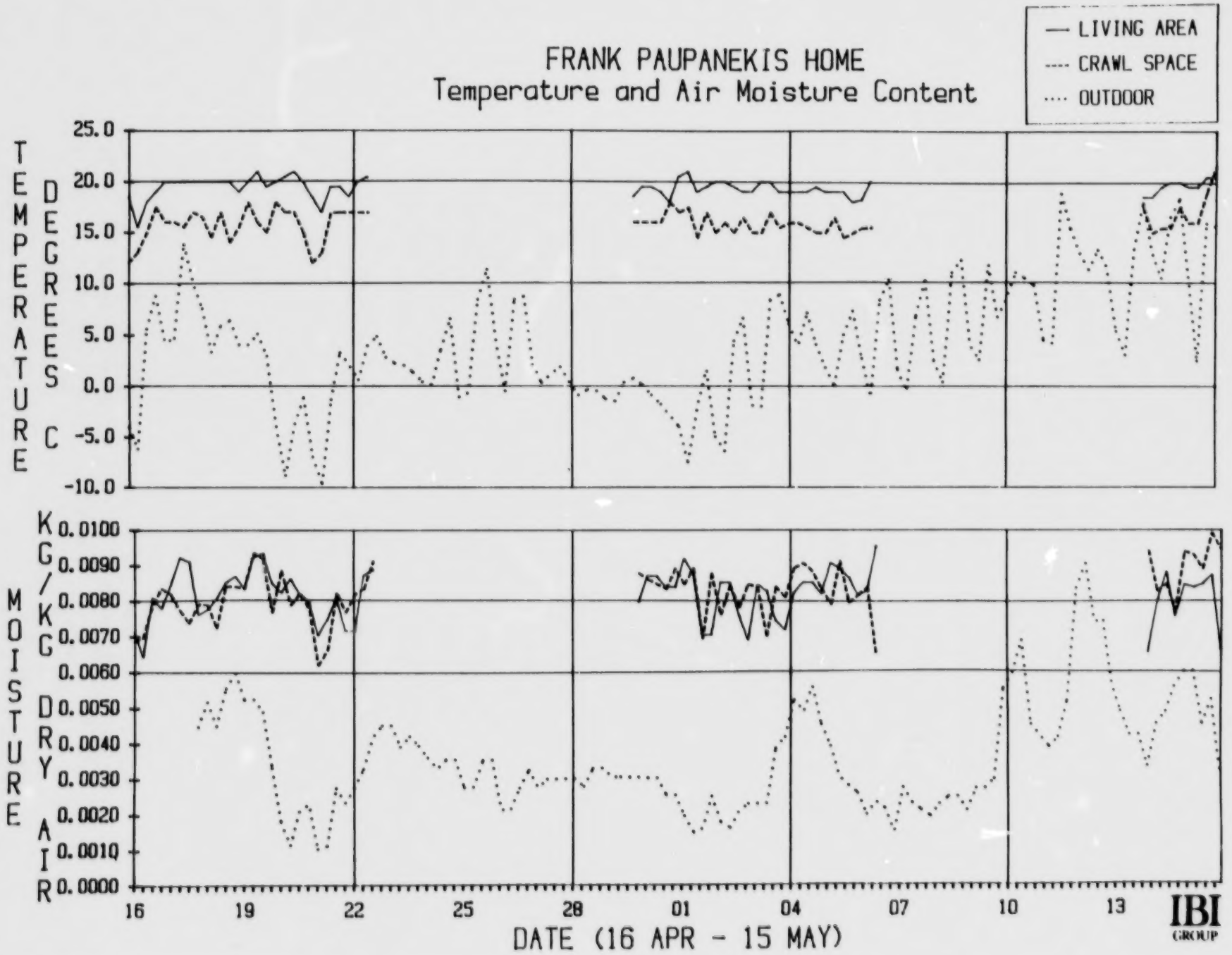
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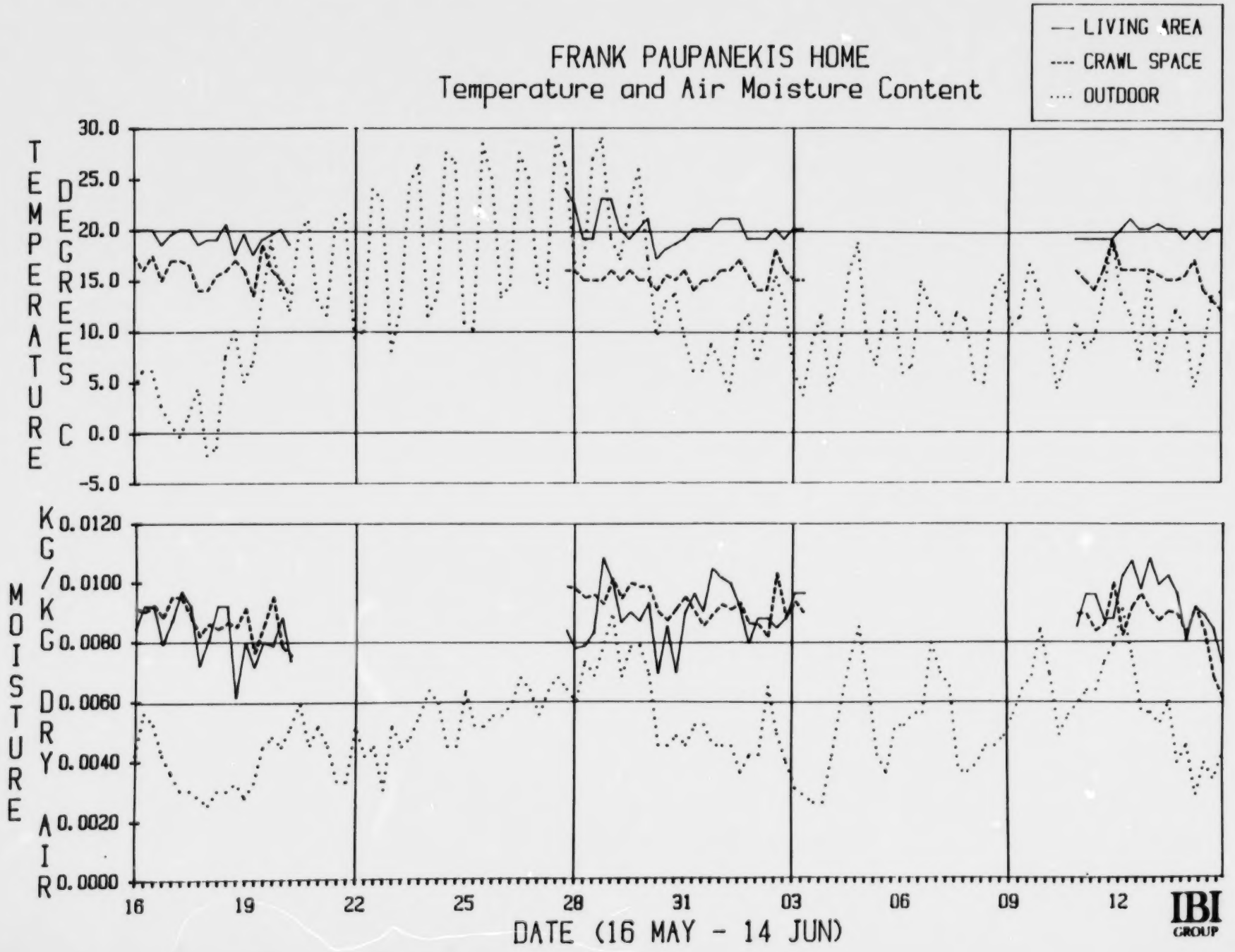
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MOISTURE KG/KG DRY AIR
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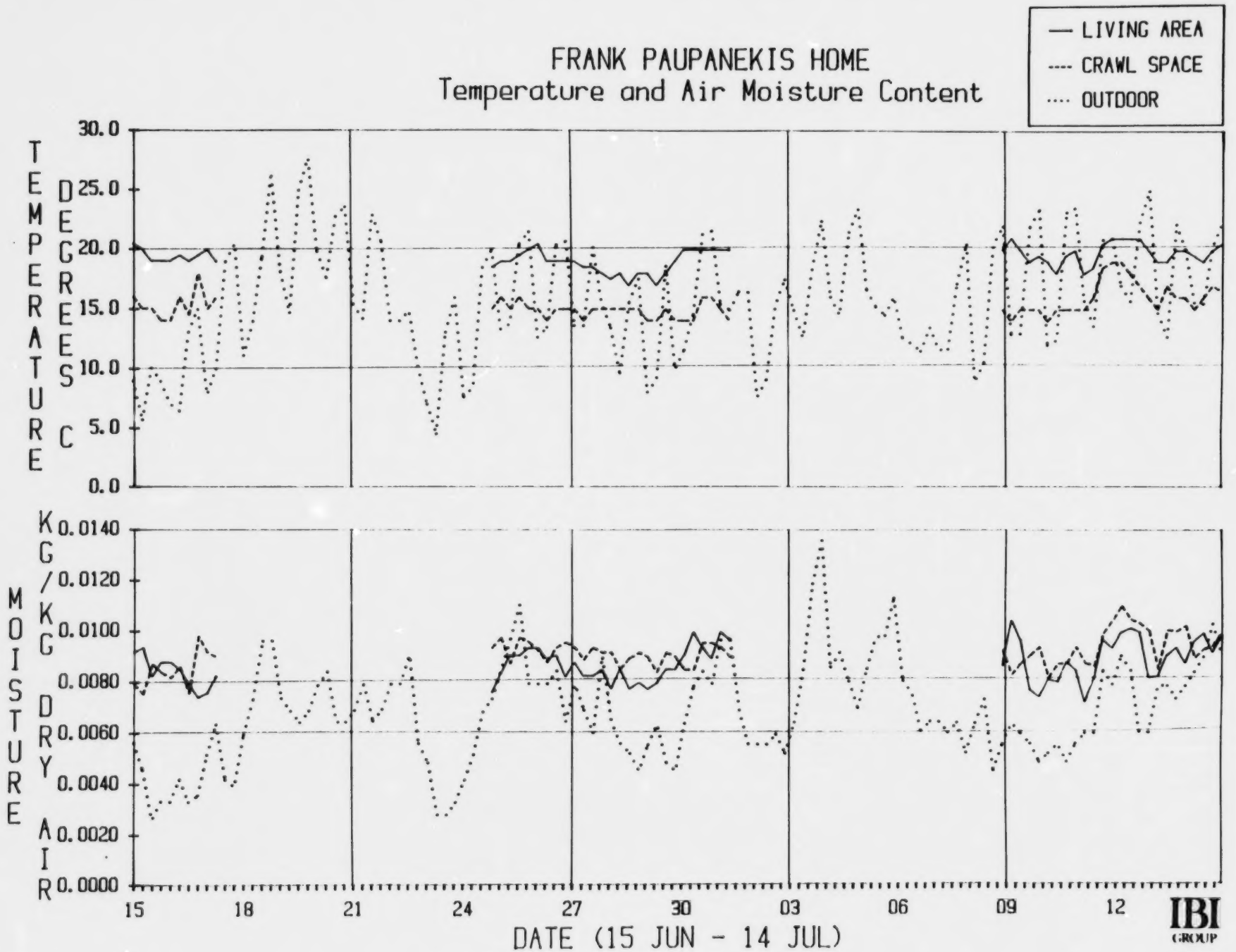
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MOISTURE KG/KG DRY AIR
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DATE (15 JUN - 14 JUL)
IBI GROUP

FLOOR SURFACE TEMPERATURE READINGS

PAUPANEKIS HOUSE

FLOOR SURFACE TEMPERATURE READINGS

DATE & TIME	CENTRE OF LIVING ROOM	CENTRE OF KITCHEN	MASTER BEDROOM	NORTH BEDROOM	EAST BEDROOM	WEST BEDROOM	BATHROOM	UTILITY ROOM
27 FEB 1:00 PM	22	22	21	21	21	21	21	22
3 MAR 2:50 PM	20	19	20	20	20	19	-	19
6 MAR 12:10 PM	19	20	20	20	20	21	21	21
14 MAR 11:30 AM	20	20	20	20	20	20	21	21
17 MAR 2:20 PM	21	21	21	20	21	21	21	21
20 MAR 2:20 PM	21	21	21	21	21	21	22	22
1 APR 1:30 PM	22	22	20	20	20	20	open 16 window	20
8 APR 10:30 AM	22	21	19	19	20	20	20	21
15 APR 10:00 AM	23	24	22	22	23	22	22	24
22 APR 11:50 AM	20	19	21	22	23	22	19	21
25 APR 1:30 PM	24	26	22	22	23	22	22	21
29 APR 11:45 AM	20	21	20	20	20	20	19	20
6 MAY 10:00 AM	23	26	21	21	24	22	23	24
13 MAY 11:35 AM	22	22	21	21	21	20	21	22
20 MAY 11:30 AM	22	23	21	21	21	21	20	23
27 MAY 12:30 PM	25	26	22	22	22	22	23	24

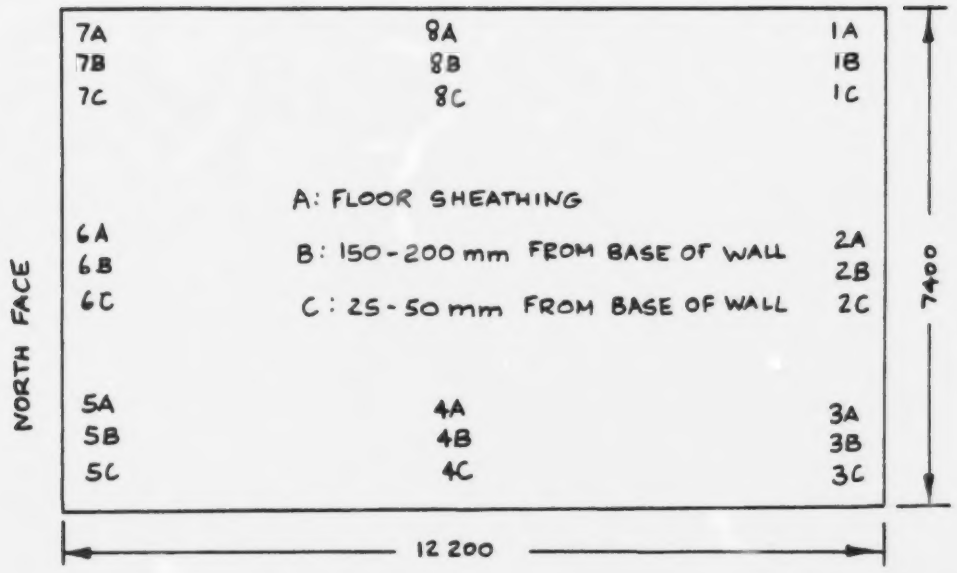
PAUPANEKIS HOUSE

FLOOR SURFACE TEMPERATURE READINGS

DATE & TIME	CENTRE OF LIVING ROOM	CENTRE OF KITCHEN	MASTER BEDROOM	NORTH BEDROOM	EAST BEDROOM	WEST BEDROOM	BATHROOM	UTILITY ROOM
3 JUN 12:35 PM	22	24	20	21	21	20	21	22
10 JUN 11:45 AM	21	22	21	21	21	21	21	21
17 JUN 11:45 AM	21	22	20	20	20	20	20	20
24 JUN 12:25 PM	21	23	21	20	20	20	21	22
1 JUL 2:00 PM	22	23	20	20	21	20	21	23
8 JUL 1:40 PM	22	24	20	21	20	20	21	22

WOOD MOISTURE CONTENT READINGS

Paupanekis House
Wood Moisture Content Location Plan



Paupanekis House
Wood Moisture Content Readings

LOCATION \ DATE		JAN 18/86 (%)	MAR 25/86 (%)	MAY 13/86 (%)	JULY 18/86 (%)
1	A	17.5	17.5	19.0	19.5
	B	18.5	17.5	29.0	26.5
	C	23.5	22.0	*	
2	A	9.0	9.0	12.0	12.0
	B	16.0	17.5	23.0	23.5
	C	19.5	17.5	25.0	
3	A	13.5	13.0	18.0	19.5
	B	19.5	20.0	26.0	*
	C	27.5	24.0	*	
4	A	13.5	15.0	17.0	18.0
	B	12.0	17.0	25.0	26.0
	C	17.5	18.0	*	
5	A	15.5	15.0	19.0	17.5
	B	17.0	19.0	28.0	28.5
	C	18.5	20.0	*	
6	A	14.0	16.0	20.0	21.5
	B	15.0	17.0	22.0	23.5
	C	17.5	18.0	*	
7	A	14.0	14.0	16.0	19.5
	B	17.5	20.0	29.0	*
	C	21.0	21.0	*	
8	A	12.5	12.0	18.0	12.5
	B	16.0	17.5	23.0	26.0
	C	18.5	19.0	25.0	

* SATURATED (≥ 30%)

APPENDIX B: TAIT HOUSE

Crawl Space Features and Retrofit Measures

Air Moisture Content and Temperature Data Charts

Floor Surface Temperature Readings

Wood Moisture Content Readings

CRAWL SPACE FEATURES AND RETROFIT MEASURES

TAIT HOUSE

OCCUPANCY: 2 adults, 2 children

DWELLING CHARACTERISTICS:

- age: 2 years;
- type: bungalow;
- dimensions: 12.2 x 7.4 m;
- gross floor area: 90.3 m^2 (includes base of exterior wall).

CRAWL SPACE FEATURES (before retrofit):

- preserved wood foundation (PWF);
- clearance height: 1120 mm with extensive heating ducts;
- insulation: sandwiched within wall - RSI 3.5 fibre glass batt;
- site drainage: very good, weeping tile internal and external to footing;
- polyethylene on crawl space floor covered with 100 mm gravel;
- soil: generally dry, visible moisture in soil around footing;
- heating: direct forced air, indirectly by heating duct radiation;
- vents: plugged up with insulation;
- [illegible]ss joists;
- extensive efflorescence on footing.

CRAWL SPACE OBSERVED PROBLEMS:

- high moisture levels in corners at base of wall and floor sheathing;
- underside of vestibule floor sheathing dripping wet.

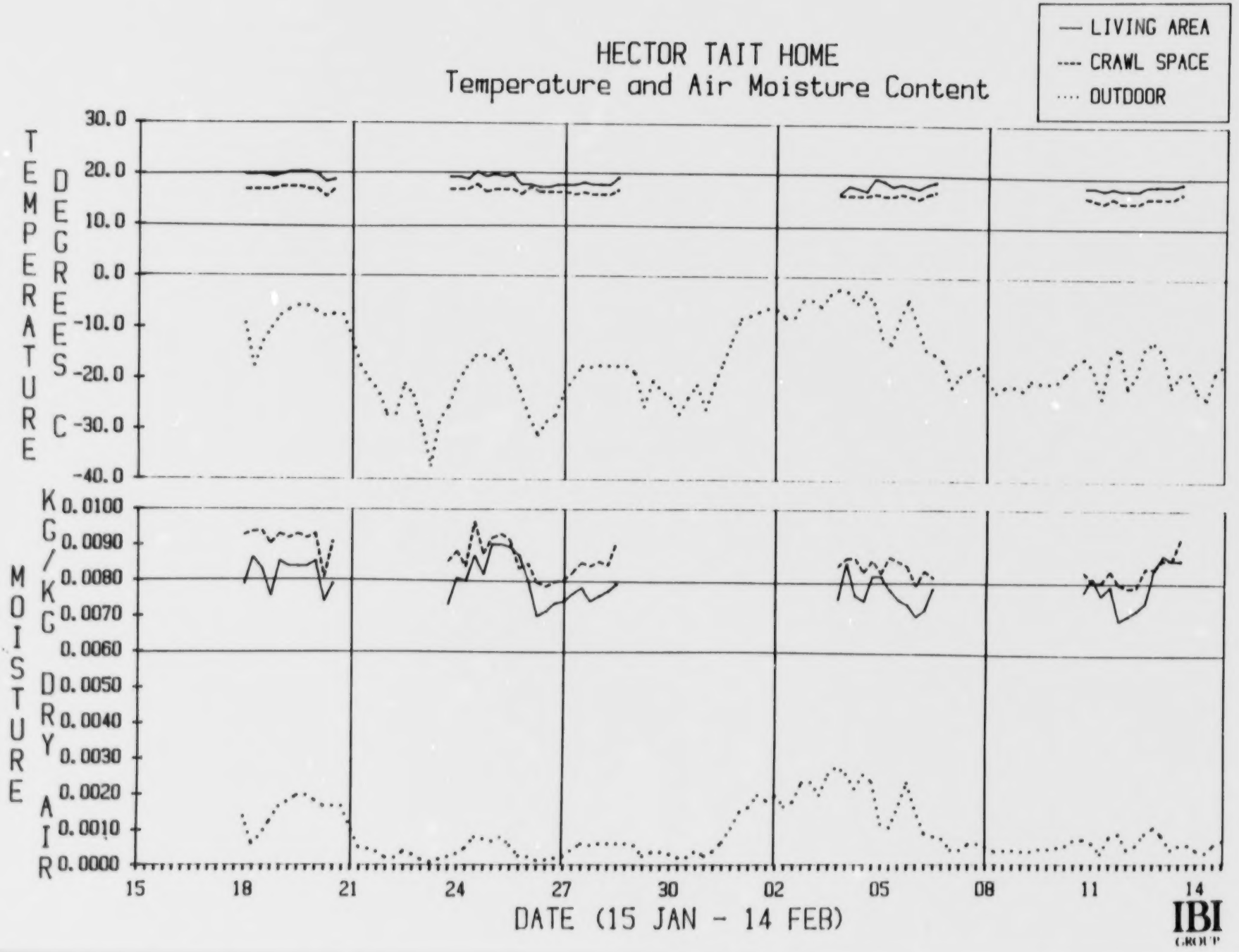
RETROFIT OBJECTIVE:

Check importance of covering the crawl space soil and footings.

RETROFIT MEASURES:

- 0.25 mm (10 mil) polyethylene film added to crawl space floor. Sealed to existing polyethylene protruding from base of PWF wall;
- sealed off vestibule crawl space from main crawl space with polyethylene;
- edge of sump pail lowered slightly below level of crawl space floor;
- edges of crawl space access hatch weatherstripped (although this measure is not significant because the forced air distribution system merges living area air with crawl space air);
- extended sump hose 4 - 5 m from house;
- provided removable insulated crawl space vent doors (RSI 4.4);
- constructed and installed three storage pallets in the crawl space near the access hatch.

AIR MOISTURE CONTENT AND TEMPERATURE DATA CHARTS


HECTOR TAIT HOME
Temperature and Air Moisture Content
— LIVING AREA
---- CRAWL SPACE
.... OUTDOOR
TEMPERATURE DEGREES C
30.0
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-30.0
-40.0
MOISTURE KG/KG DRY AIR
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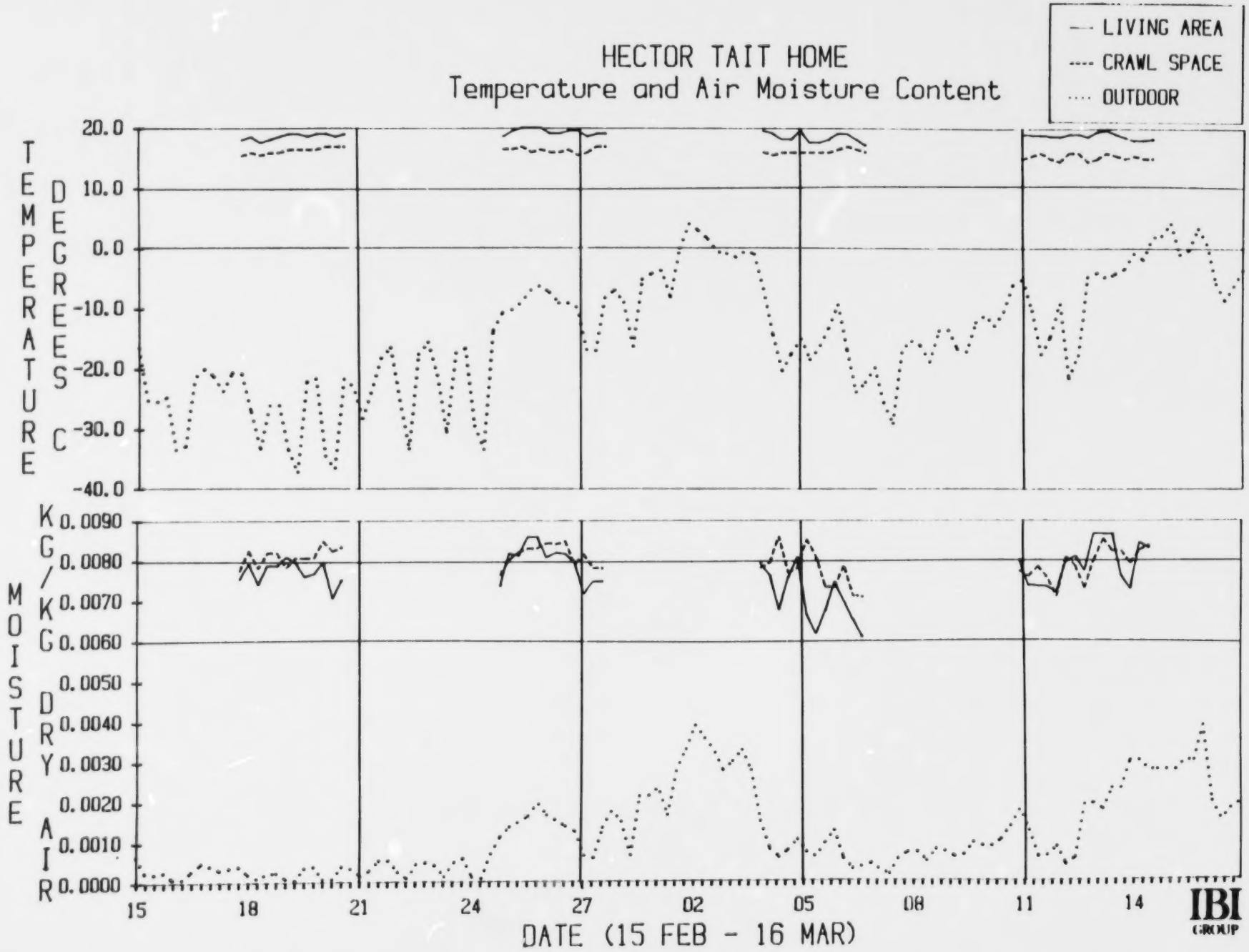
DATE (15 JAN - 14 FEB)
IBI GROUP


HECTOR TAIT HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
MOISTURE KG/KG DRY AIR
0.0090
0.0080
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0.0060
0.0050
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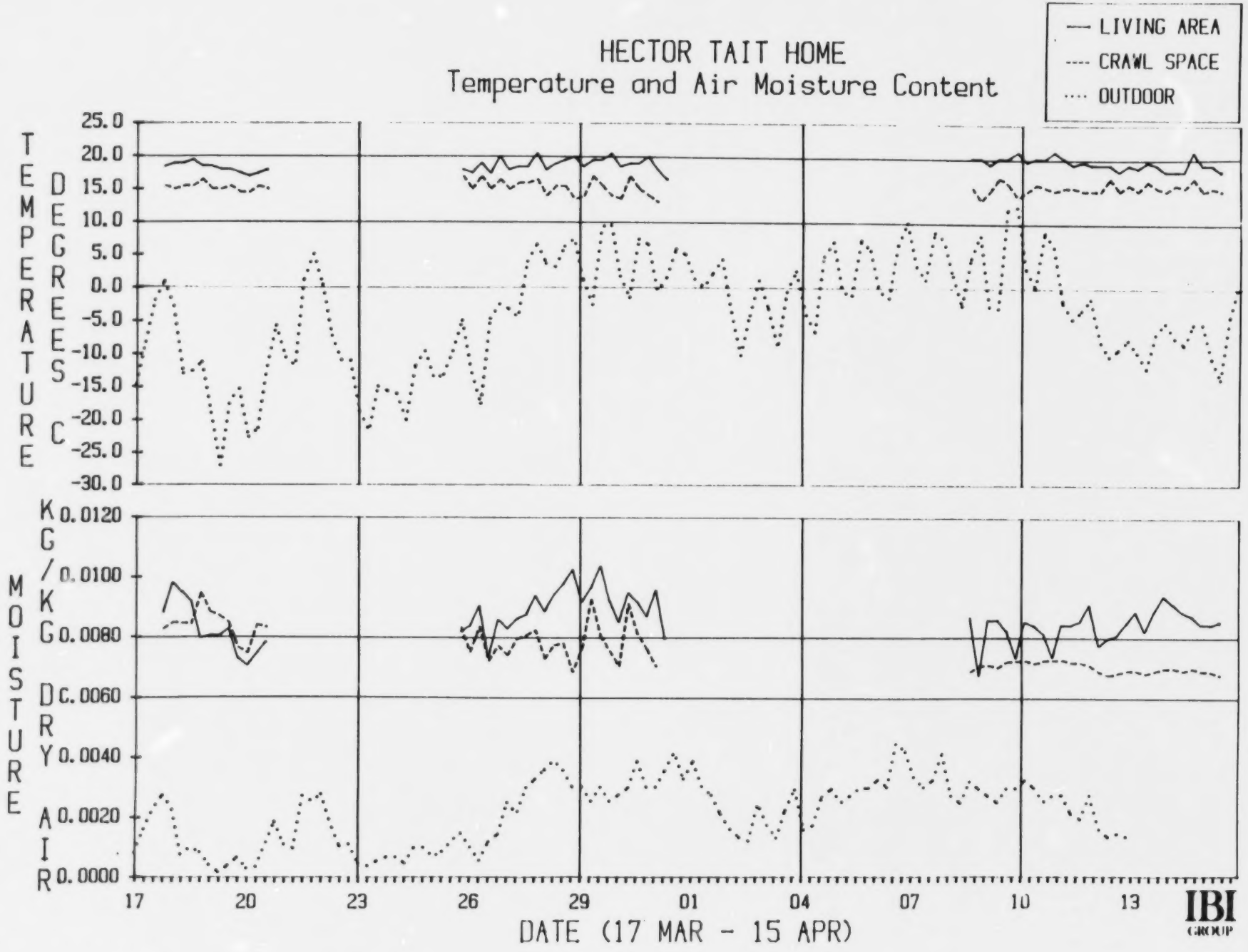
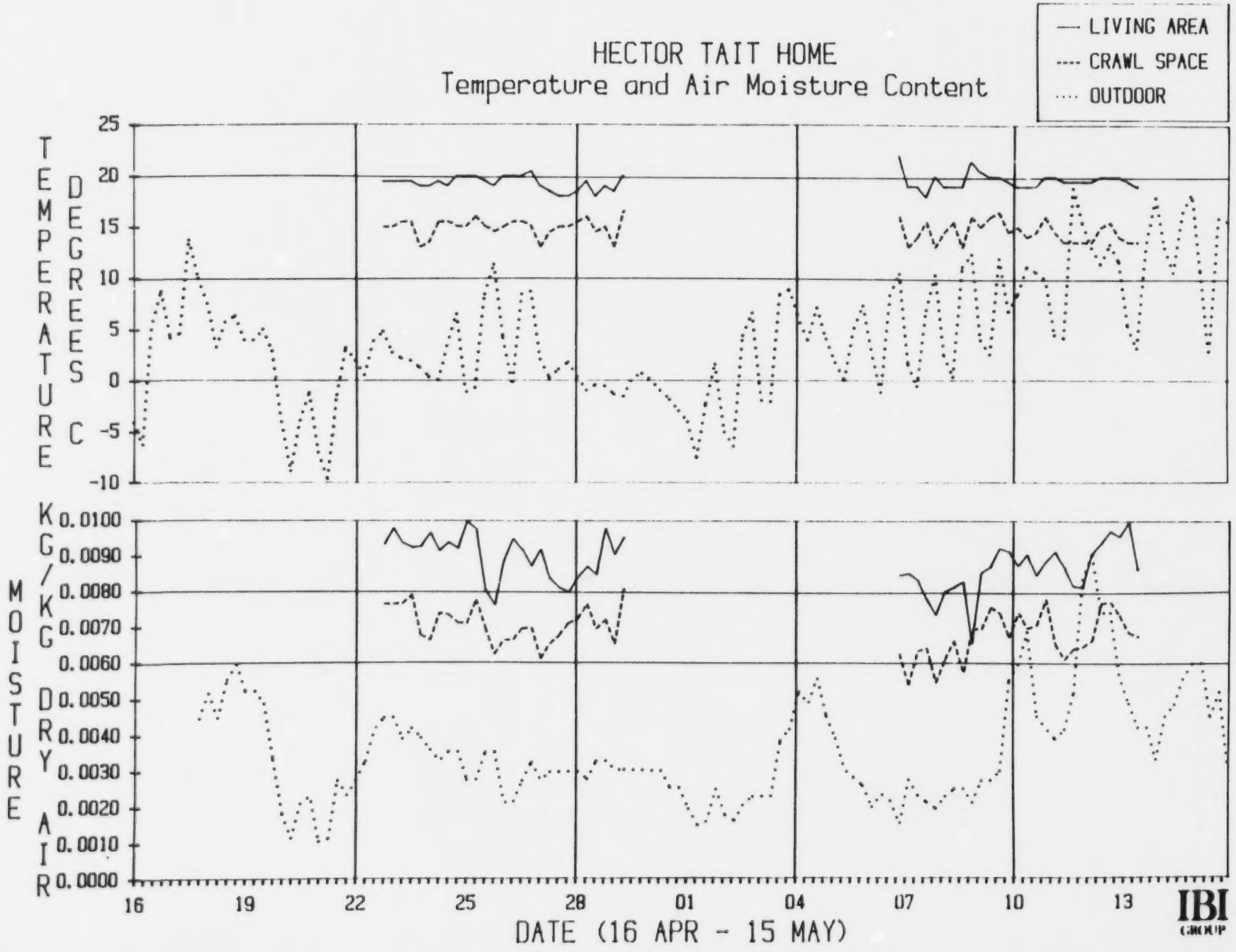
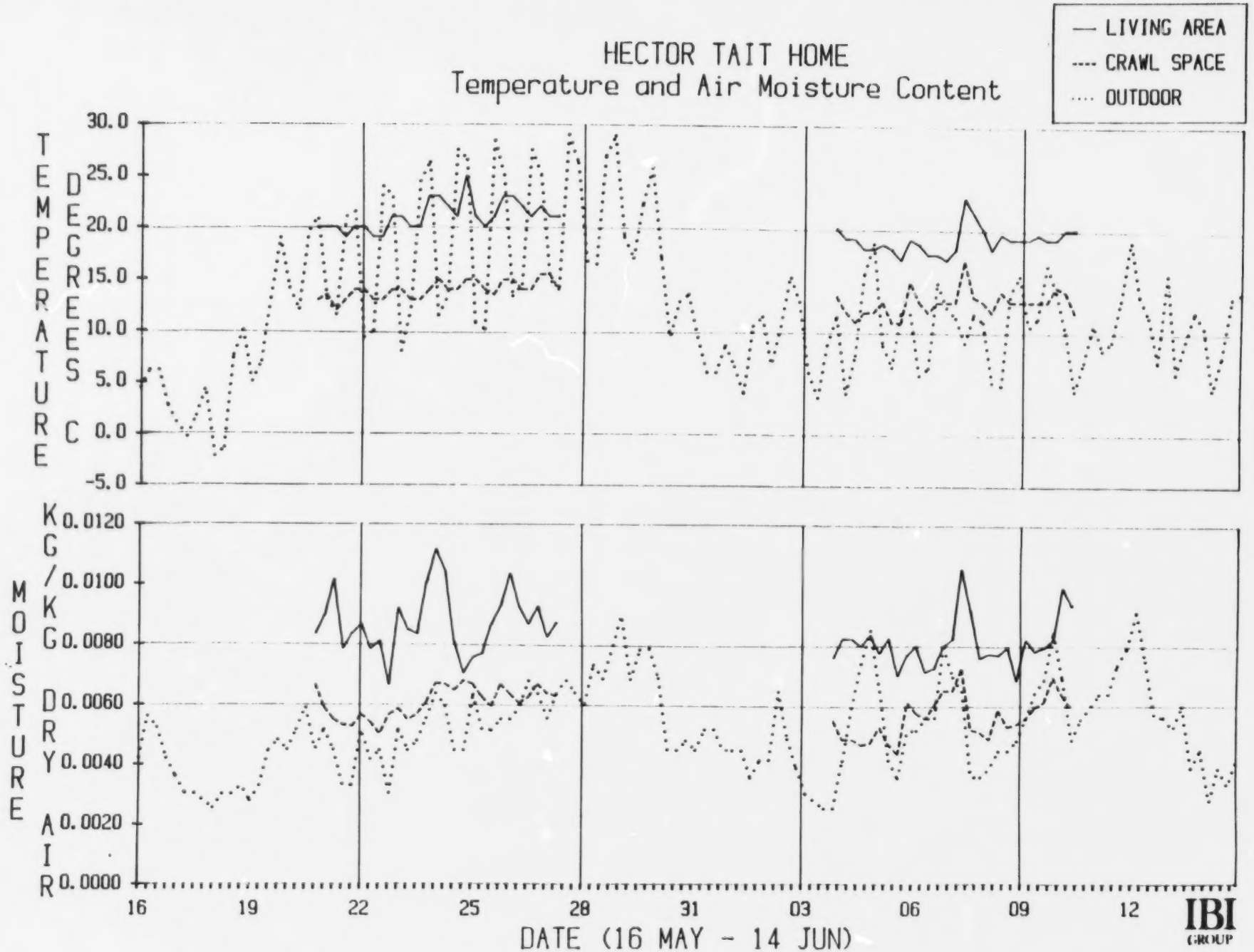
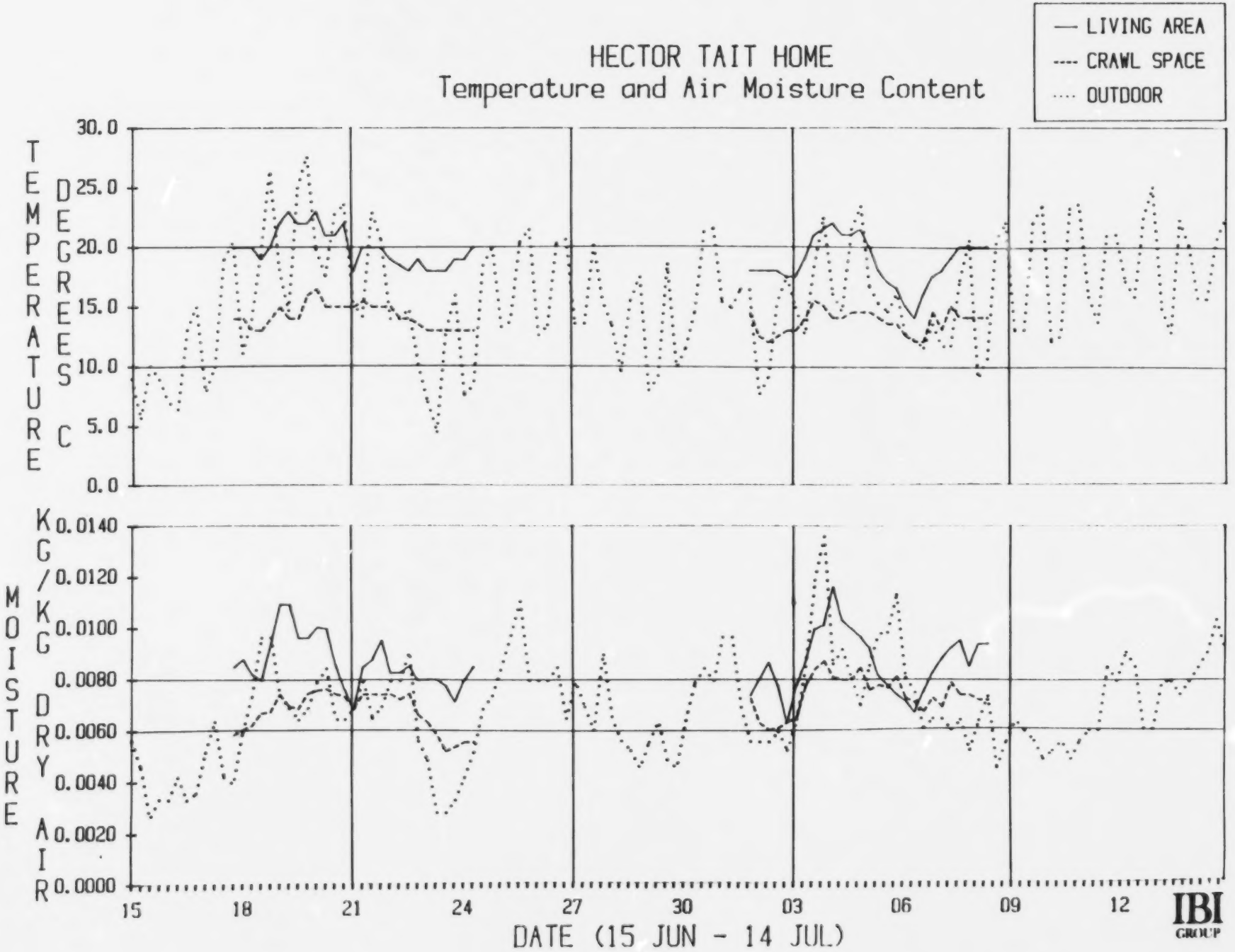
14
DATE (15 FEB - 16 MAR)
IBI GROUP


HECTOR TAIT HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE
DEGREES C
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
MOISTURE
KG/KG DRY AIR
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
17
20
23
26
29
01
04
07
10
13
DATE (17 MAR - 15 APR)
IBI
GROUP


HECTOR TAIT HOME
Temperature and Air Moisture Content
— LIVING AREA
---- CRAWL SPACE
.... OUTDOOR
TEMPERATURE DEGREES C
25
20
15
10
5
0
-5
-10
MOISTURE AIR KG/KG DRY
0.0100
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
16
19
22
25
28
01
04
07
10
13
DATE (16 APR - 15 MAY)
IBI GROUP


HECTOR TAIT HOME
Temperature and Air Moisture Content
— LIVING AREA
---- CRAWL SPACE
.... OUTDOOR
TEMPERATURE DEGREES C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
MOISTURE KG/KG DRY AIR
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
16
19
22
25
28
31
03
06
09
12
DATE (16 MAY - 14 JUN)
IBI GROUP


HECTOR TAIT HOME
Temperature and Air Moisture Content
— LIVING AREA
---- CRAWL SPACE
.... OUTDOOR
TEMPERATURE DEGREES C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
MOISTURE KG/KG DRY AIR
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
15
18
21
24
27
30
03
06
09
12
DATE (15 JUN - 14 JUL)
IBI GROUP

FLOOR SURFACE TEMPERATURE READINGS

TAIT HOUSE

FLOOR SURFACE TEMPERATURE READINGS

DATE & TIME	CENTRE OF LIVING ROOM	CENTRE OF KITCHEN	MASTER BEDROOM	EAST BEDROOM	S.E. BEDROOM	BATHROOM	UTILITY ROOM	
27 FEB 12:30 PM	22	22	22	22	22	23	23	
3 MAR 3:25 PM	23	23	22	22	22	23	23	
6 MAR 11:50 AM	18	19	19	19	20	20	19	
14 MAR 11:15 AM	22	22	21	21	22	22	22	
17 MAR 2:40 PM	20	20	21	22	21	22	20	
20 MAR 2:40 PM	21	21	21	21	21	22	21	
1 APR 1:15 PM	24	24	24	23	24	24	24	
8 APR 11:00 AM	22	22	22	22	21	23	23	
15 APR 10:20 AM	20	20	20	20	19	20	20	
22 APR 11:40 AM	23	23	23	23	23	23	24	
25 APR 1:35 PM	21	21	20	20	20	20	20	
29 APR 11:40 AM	21	19	21	21	21	21	21	
6 MAY 10:25 AM	23	23	22	21	21	22	22	
13 MAY 11:15 AM	22	21	21	20	20	21	20	
20 MAY 11:45 AM	23	22	21	21	20	20	21	
27 MAY 12:10 PM	26	25	23	23	23	22	24	

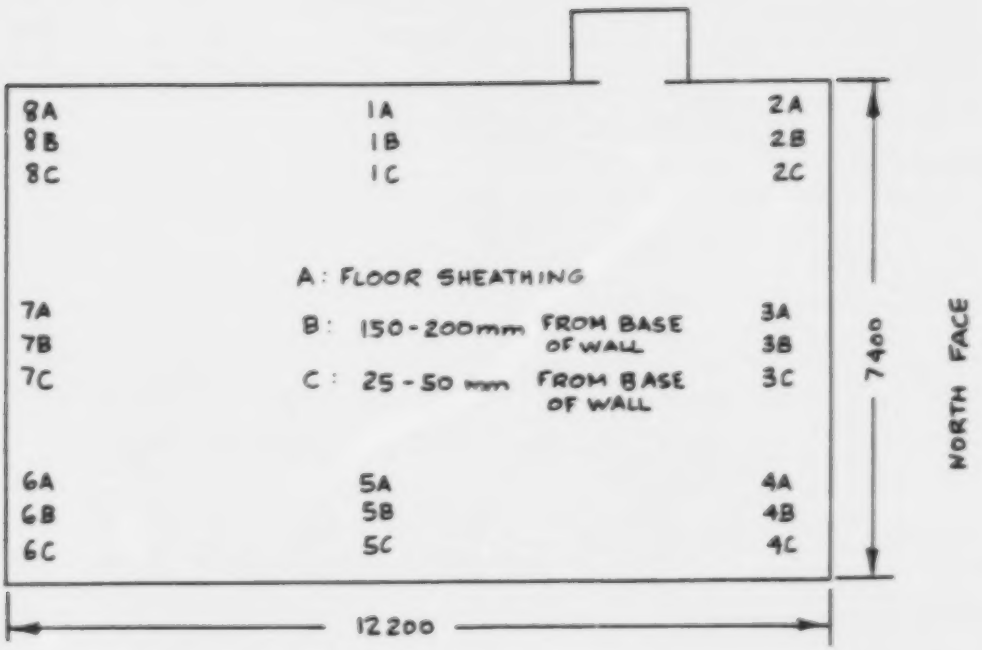
TAIT HOUSE

FLOOR SURFACE TEMPERATURE READINGS

DATE & TIME	CENTRE OF LIVING ROOM	CENTRE OF KITCHEN	MASTER BEDROOM	EAST BEDROOM	S.E. BEDROOM	BATHROOM	UTILITY ROOM	
3 JUN 12:55 PM	21	22	21	22	21	21	21	
10 JUN 11:30 AM	21	21	22	21	21	21	21	
17 JUN 11:15 AM	21	21	21	21	21	20	20	
24 JUN 12:25 PM	21	20	21	21	20	20	20	
1JUL 1:55 PM	24	23	22	21	21	21	23	
8 JUL 1:45 PM	22	23	23	22	22	23	23	

WOOD MOISTURE CONTENT READINGS

Tait House
Wood Moisture Content Location Plan



FRONT

Tait House
Wood Moisture Content Readings

LOCATION \ DATE		JAN 17/86 (%)	MAR 25/86 (%)	MAY 15/86 (%)	JULY 8/86 (%)
1	A	11.5	18.0	16.0	18.0
	B	20.0	26.0	22.0	26.0
	C	*			
2	A	*	24.0	22.0	21.0
	B	20.5	24.0	29.0	26.0
	C	*			
3	A	21.5	20.0	21.0	20.0
	B	16.5	22.0	23.0	24.0
	C	*			
4	A	*	19.0	18.0	21.0
	B	28.5	28.0	29.0	*
	C	*			
5	A	18.0	18.0	21.0	21.0
	B	22.0	24.0	23.0	27.0
	C	*			
6	A	*	23.0	25.0	25.5
	B	*	21.0	29.0	27.0
	C	*			
7	A	*	16.0	23.0	20.0
	B	20.5	28.0	29.0	25.0
	C	25.5			
8	A	*	20.5	22.0	19.0
	B	26.5	*	29.0	26.5
	C	*			

* SATURATED (≥30%)

APPENDIX C: LAUGHER HOUSE

Crawl Space Features and Retrofit Measures

Air Moisture Content and Temperature Data Charts

Floor Surface Temperature Readings

Wood Moisture Content Readings

CRAWL SPACE FEATURES AND RETROFIT MEASURES

LAUGHER HOUSE

OCCUPANCY: 2 adults, 3 children

DWELLING CHARACTERISTICS:

- age: 7 years;
- type: bungalow;
- dimensions: 13.4 x 7.4 m;
- gross floor area: 99.2 m^2.

CRAWL SPACE FEATURES (before retrofit):

- concrete foundation;
- clearance height: 760 mm;
- insulation: headers - RSI 3.5 glass fibre batt
  walls - 50 mm expanded polystyrene (type 2)
  footings - not insulated;
- site drainage: poor, seasonal flooding;
- polyethylene film on crawl space floor, inadequately covering the footing;
- heating: baseboard heater, centrally located, set on very low setting;
- vents: closed but not insulated.

CRAWL SPACE OBSERVED PROBLEMS:

- polyethylene degraded;
- 450 mm (18 in.) diameter hole, 75 mm (3 in.) deep filled with water was found in the crawl space;
- sump pit exposed to the crawl space air;
- the sill plate had significant frost build-up;
- the header insulation was frozen on.

RETROFIT OBJECTIVE:

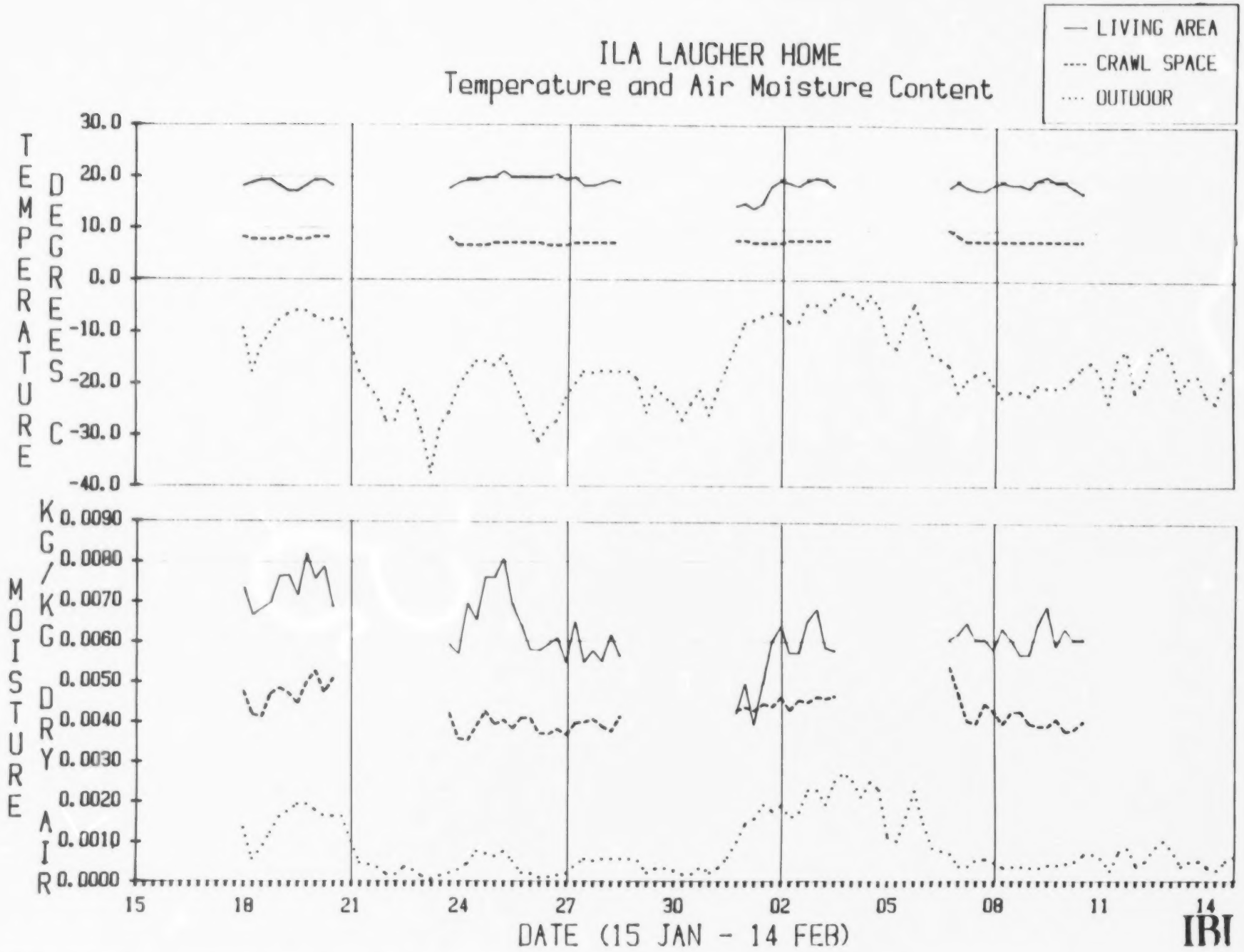
Separate crawl space from soil.

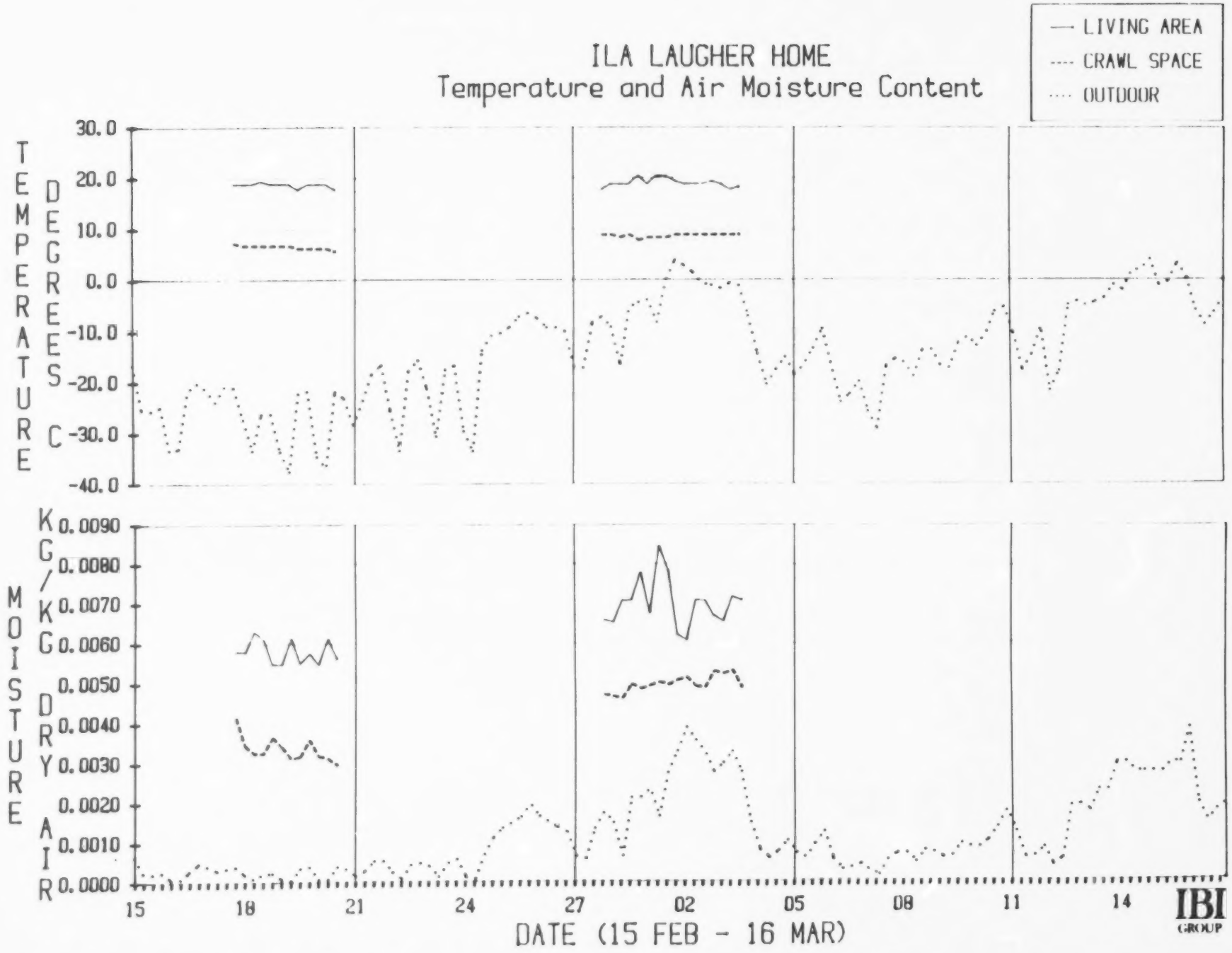
RETROFIT MEASURES:

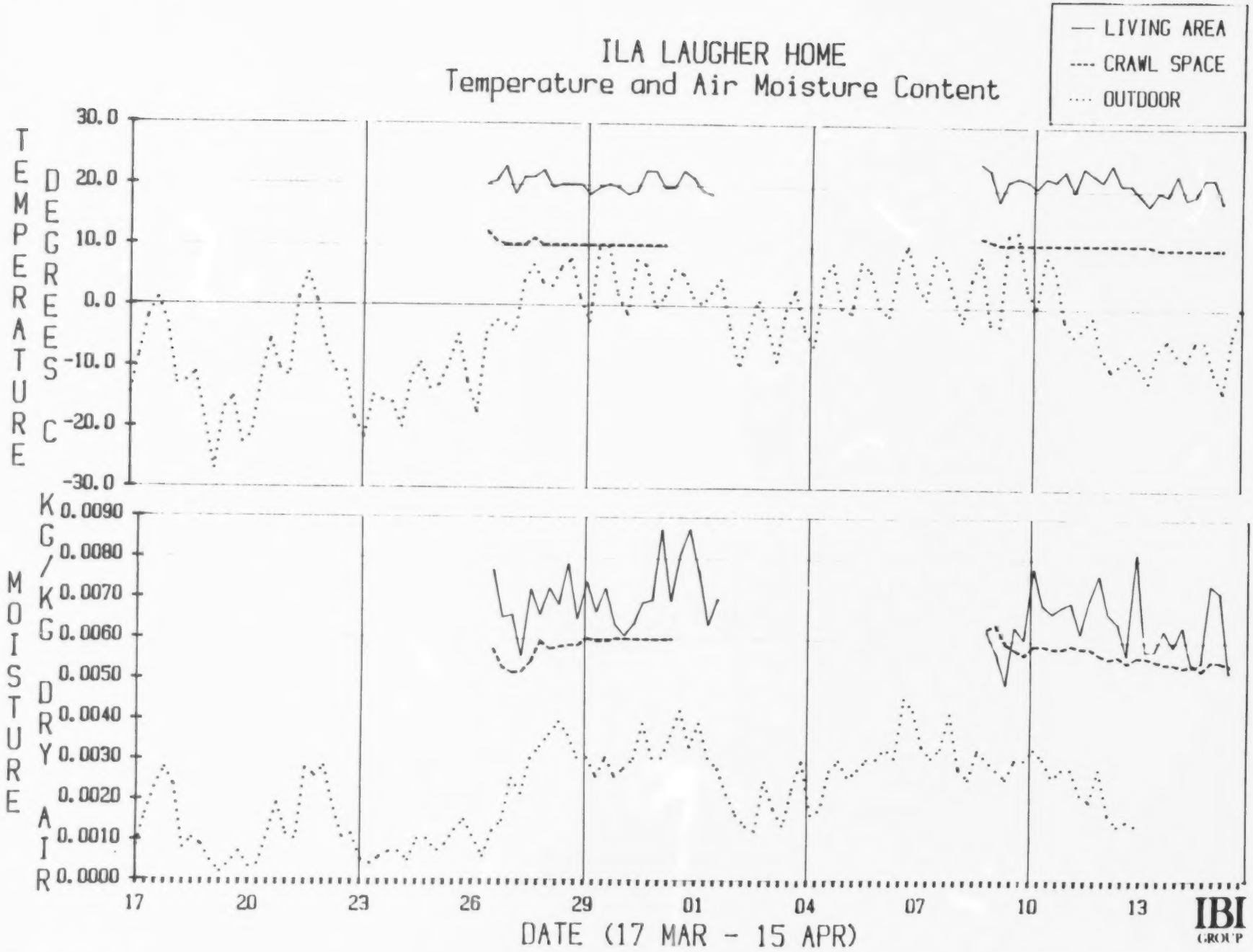
- polyethylene film added to crawl space floor;

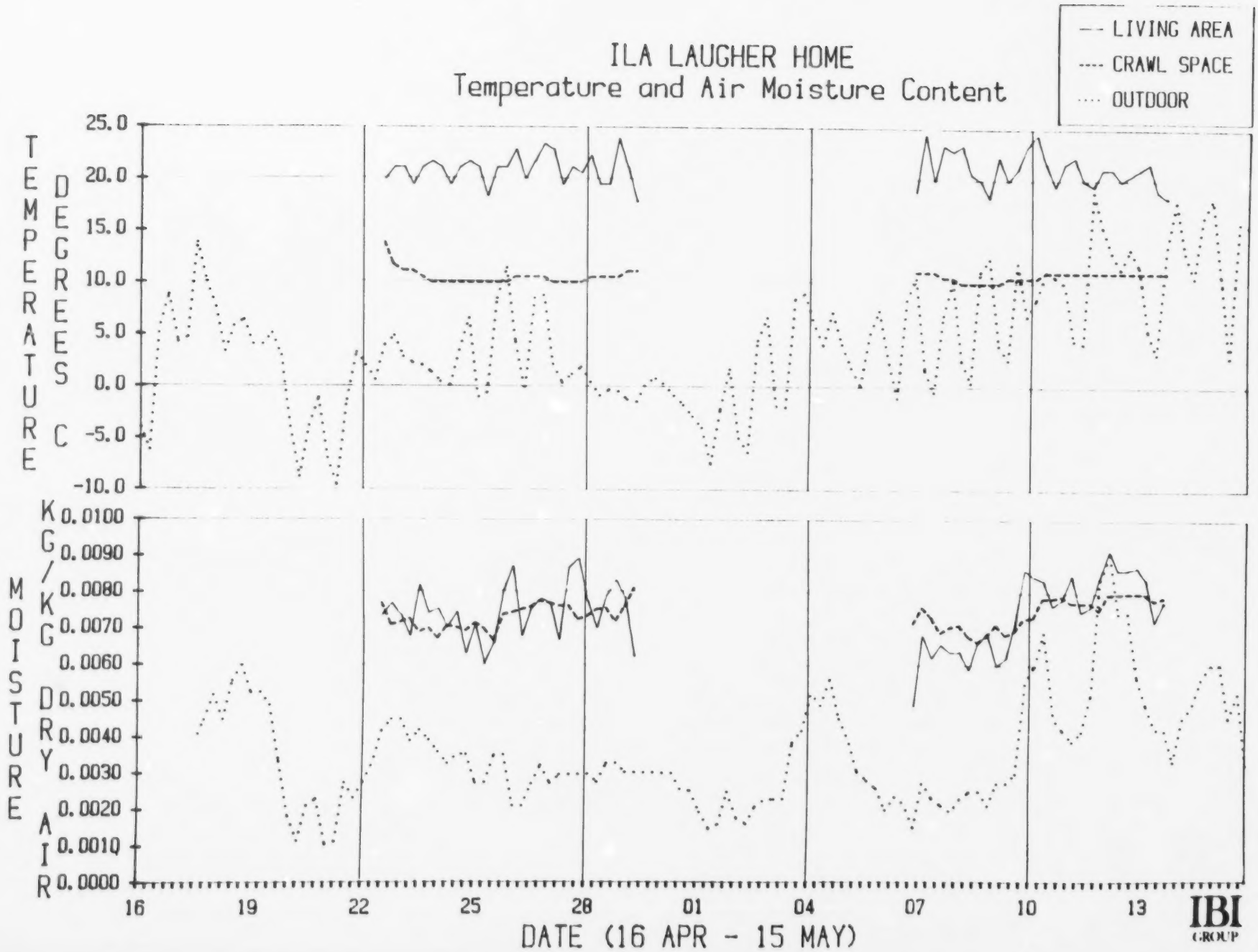
- o 0.25 mm (10 mil) polyethylene sealed to base of foundation wall insulation and to top of founation wall;
- o water in the water hole removed and hole filled with gravel prior to applying polyethylene;
- o ice on sill plate removed;
- o provided polyethylene lined cover for sump pump;
  - edge of sump pail lowered slightly below level of crawl space floor;
  - new polyethylene fastened to lip of sump pail;
  - plywood cover with polyethylene underside sealed around sump hose and electrical cord;
- o edges of crawl space access hatch weatherstripped;
- o sump hose extended 4 - 5 m from house;
- o provided removable insulated crawl space vent doors (RSI 4.4);
- o constructed and installed three storage pallets in the crawl space near the access hatch;
- o added a 1500 W Superior fan forced heater (15 amps) to the crawl space.

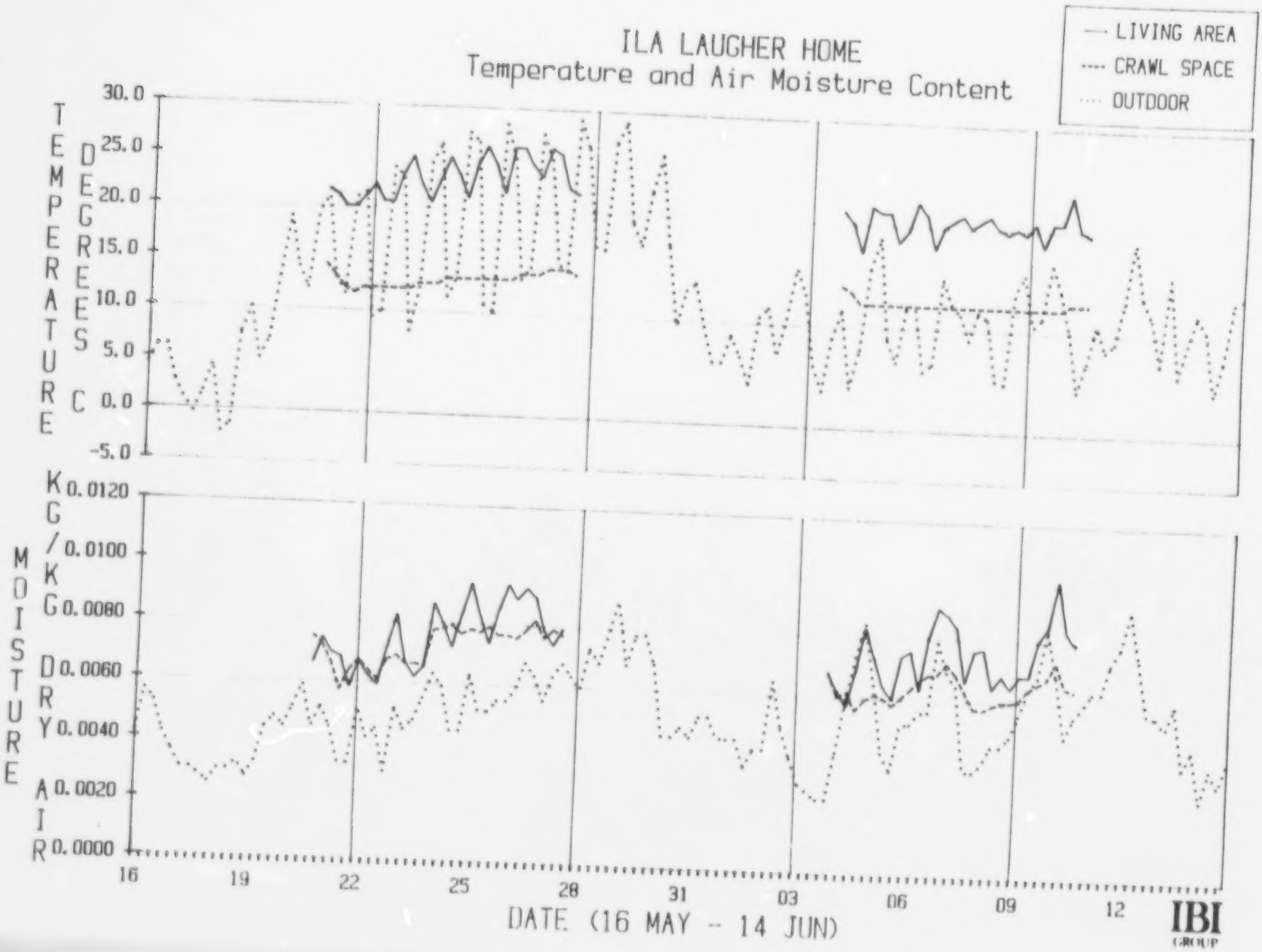
AIR MOISTURE CONTENT AND TEMPERATURE DATA CHARTS

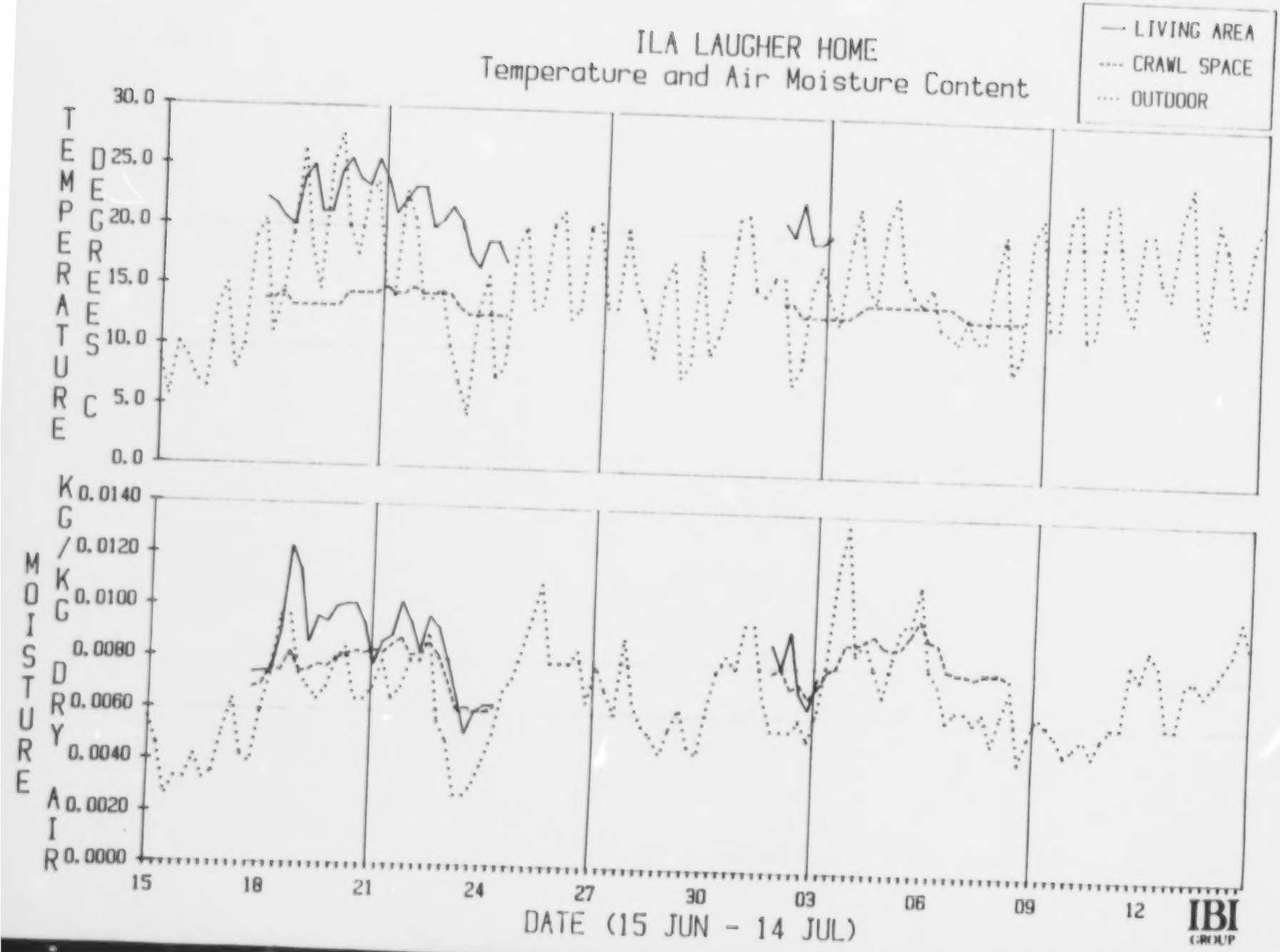

ILA LAUGHER HOME
Temperature and Air Moisture Content
— LIVING AREA
---- CRAWL SPACE
···· OUTDOOR
TEMPERATURE DEGREES C
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
MOISTURE KG/KG DRY AIR
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
15
18
21
24
27
30
02
05
08
11
14
DATE (15 JAN - 14 FEB)
IBI


ILA LAUGHER HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
MOISTURE KG/KG DRY AIR
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
15
18
21
24
27
02
05
08
11
14
DATE (15 FEB - 16 MAR)
IBI GROUP


ILA LAUGHER HOME
Temperature and Air Moisture Content
— LIVING AREA
---- CRAWL SPACE
.... OUTDOOR
TEMPERATURE DEGREES C
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
MOISTURE KG/KG DRY AIR
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
17
20
23
26
29
01
04
07
10
13
DATE (17 MAR - 15 APR)
IBI GROUP


ILA LAUGHER HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
MOISTURE AIR KG/KG DRY
0.0100
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
16
19
22
25
28
01
04
07
10
13
DATE (16 APR - 15 MAY)
IBI GROUP


ILA LAUGHER HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
MOISTURE KG/KG DRY AIR
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
16
19
22
25
28
31
03
06
09
12
DATE (16 MAY - 14 JUN)
IBI
GROUP


ILA LAUGHER HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
MOISTURE AIR KG/KG DRY KG
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
15
18
21
24
27
30
03
06
09
12
DATE (15 JUN - 14 JUL)
IBI GROUP

FLUOR SURFACE TEMPERATURE READINGS

LAUGHER HOUSE

FLOOR SURFACE TEMPERATURE READINGS

DATE & TIME	CENTRE OF LIVING ROOM	CENTRE OF KITCHEN	MASTER BEDROOM	WEST BEDROOM	EAST BEDROOM	NORTH BEDROOM	BATHROOM	UTILITY ROOM
27 FEB 12 NOON	18	18	15	18	17	-	-	16
3 MAR 1:30 PM	18	17	16	17	17	16	17	-
1 APR 1:45 PM	18	19	16	16	16	16	17	17
8 APR 12:15 PM	17	16	17	19	17	17	17	19
15 APR 11:30 AM	18	17	17	18	17	17	18	17
22 APR 11:05 AM	19	20	18	19	18	18	19	19
25 APR 2:00 PM	19	20	18	17	17	19	17	18
29 APR 10:50 AM	18	18	17	17	17	16	18	17
6 MAY 11:45 AM	18	19	18	18	18	17	18	18
13 MAY 1:15 PM	18	19	17	17	17	16	18	17
20 MAY 2:15 PM	22	22	19	18	20	18	21	20
27 MAY 12:45 PM	24	24	22	22	23	22	23	23
3 JUN 1:05 PM	18	20	18	18	17	17	18	18
10 JUN 1:30 PM	19	20	20	18	17	17	19	19
17 JUN 11:50 AM	21	21	19	18	17	18	18	20
24 JUN 12:40 PM	21	20	20	18	19	21	19	21

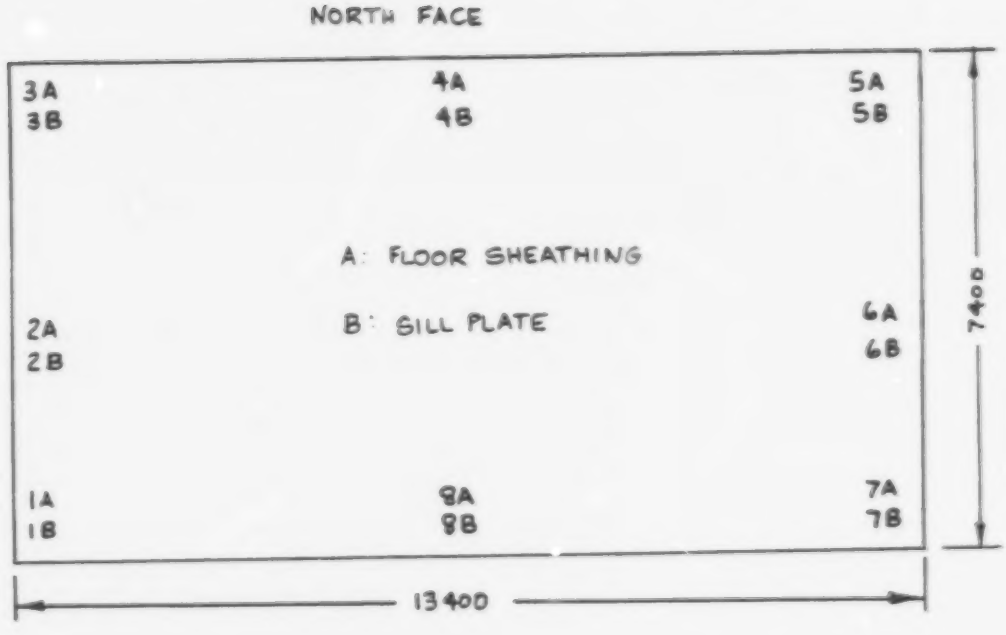
LAUGHER HOUSE

FLOOR SURFACE TEMPERATURE READINGS

DATE & TIME	CENTRE OF LIVING ROOM	CENTRE OF KITCHEN	MASTER BEDROOM	WEST BEDROOM	EAST BEDROOM	NORTH BEDROOM	BATHROOM	UTILITY ROOM
1 JUL 2:40 PM	22	22	22	20	21	22	19	20

WOOD MOISTURE CONTENT READINGS

Laugher House
Wood Moisture Content Location Plan



Laugher House
Wood Moisture Content Readings

LOCATION \ DATE		JAN 17/86 (%)	MAR 25/86 (%)	MAY 13/86 (%)	JULY 8/86 (%)
1	A	19.0	20.0	2 0	21 0
	B	*	*	*	25 0
2	A	11 0	12 0	*	21 0
	B	*	26.5	29 0	28 0
3	A	19 0	17 5	17 0	20 0
	B	*	*	*	29 0
4	A	*	22	25 0	0
	B	*	29	29 0	29 0
5	A	*	23	25 0	29 0
	B	*	*	*	*
6	A	22.0	19 0	21 5	*
	B	*	*	28 0	15 0
7	A	19.0	17 5	18 0	21 5
	B	*	*	*	15 0
8	A	*	19.0	22.0	28 0
	B	29.0	26.0	27 0	24 0

* SATURATED (>30%)

APPENDIX D: ARTHURSON HOUSE

Crawl Space Features and Retrofit Measures

Air Moisture Content and Temperature Data Charts

Floor Surface Temperature Readings

Wood Moisture Content Readings

CRAWL SPACE FEATURES AND RETROFIT MEASURES

ARTHURSON HOUSE

OCCUPANCY: 6 adults, 3 children

DWELLING CHARACTERISTICS:

- age: 6 years;
- type: bungalow;
- dimensions: 13.4 x 7.4 m;
- gross floor area: 99.2 m^2 (includes base of exterior wall).

CRAWL SPACE FEATURES (before retrofit):

- concrete foundation;
- clearance height: 890 mm;
- insulation: headers - 64 mm extruded polystyrene
  walls - 50 mm expanded polystyrene (type 2)
  footings - not insulated;
- site drainage: good;
- polyethylene film on crawl space floor covered with a thin layer of gravel;
- heating: no direct source, baseboard heater not plugged in;
- vents: plugged up with insulation.

CRAWL SPACE OBSERVED PROBLEMS:

- polyethylene film severely punctured;
- wet silty-clay immediately under polyethylene film;
- sump pit exposed to crawl space air.

RETROFIT OBJECTIVE:

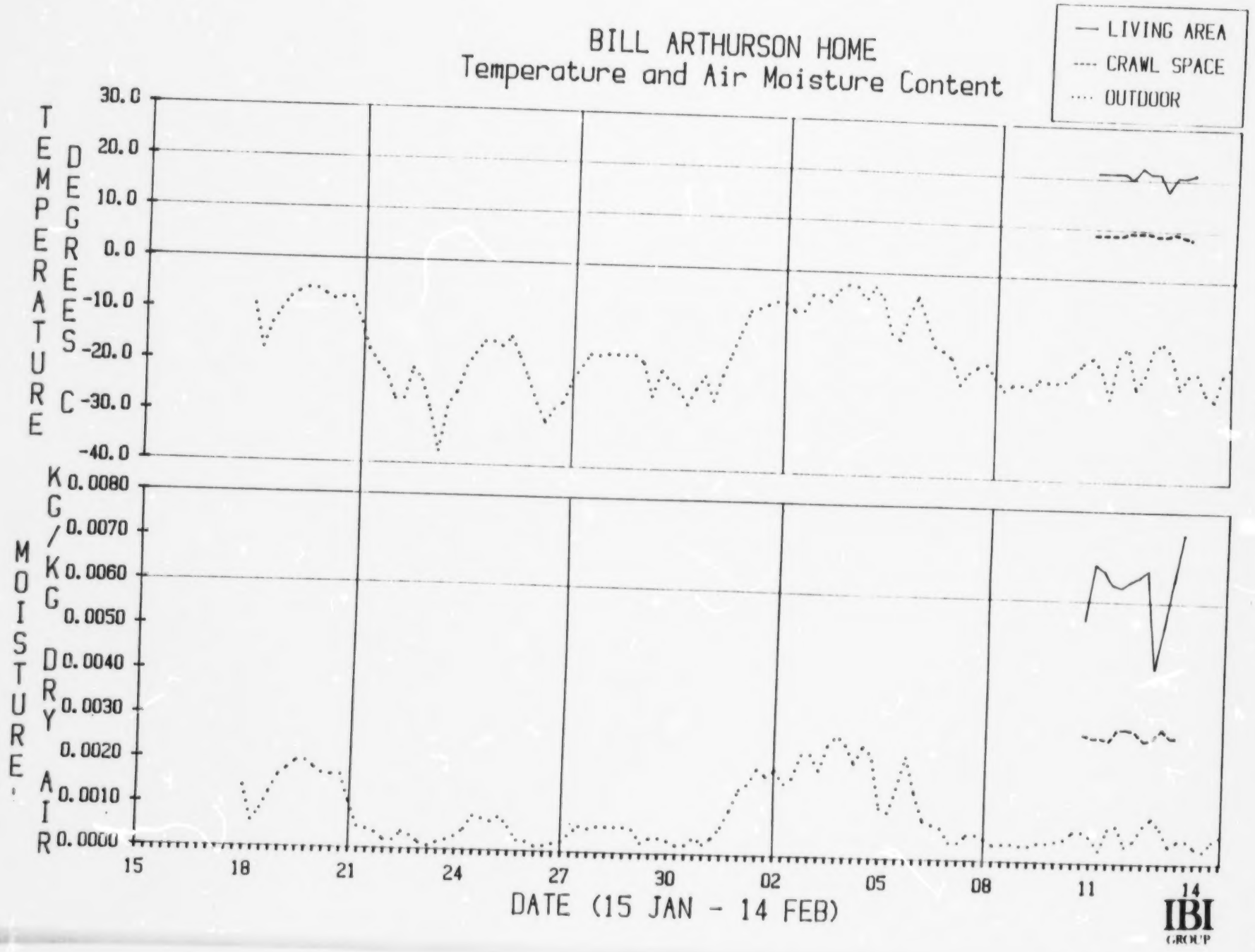
Test the effect of isolating the crawl space by sealing it off from the soil and from the living area above. Our hypothesis is that the severe living area moisture problems encountered in the past are directly due to high occupancy levels.

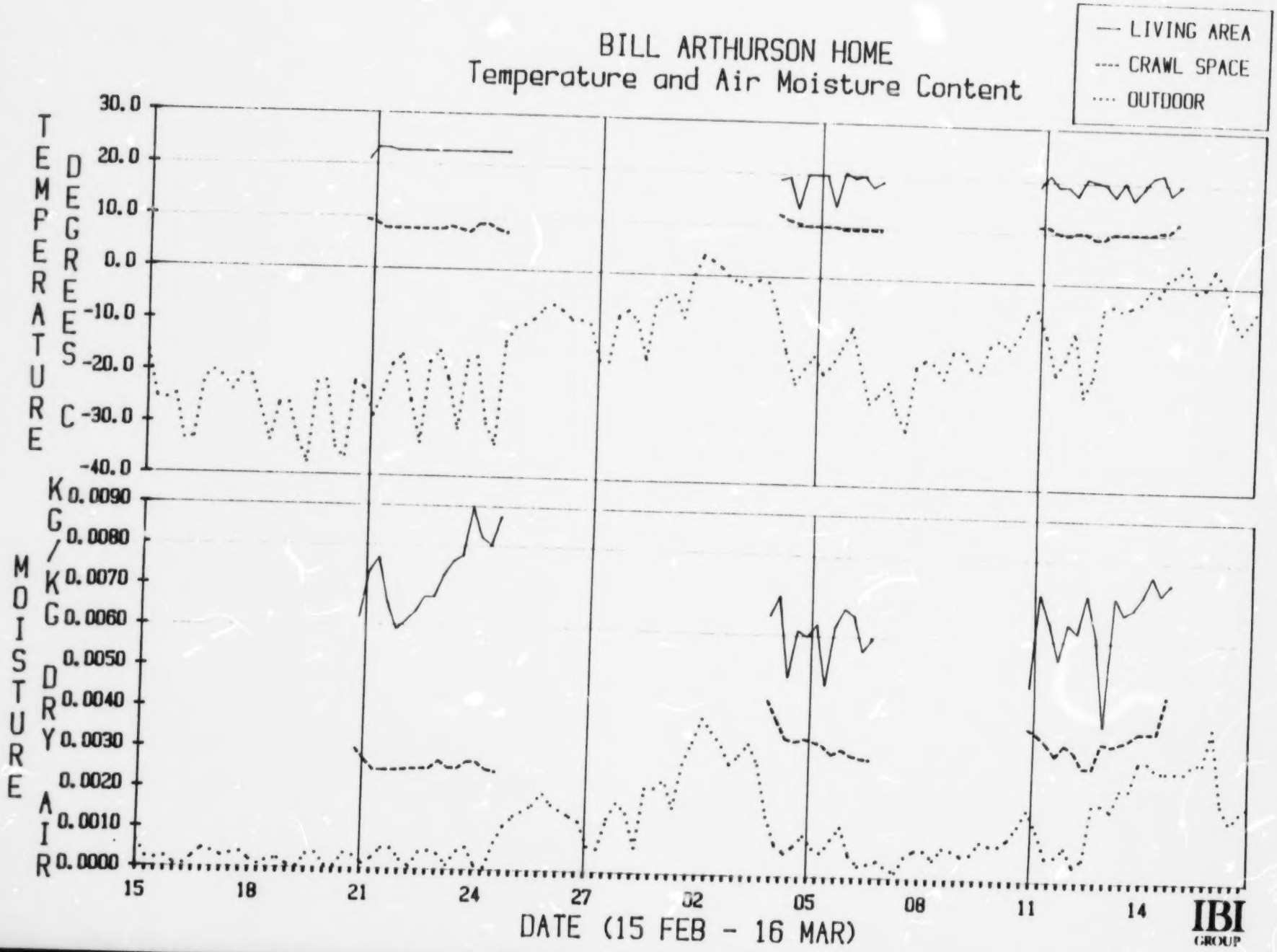
RETROFIT MEASURES:

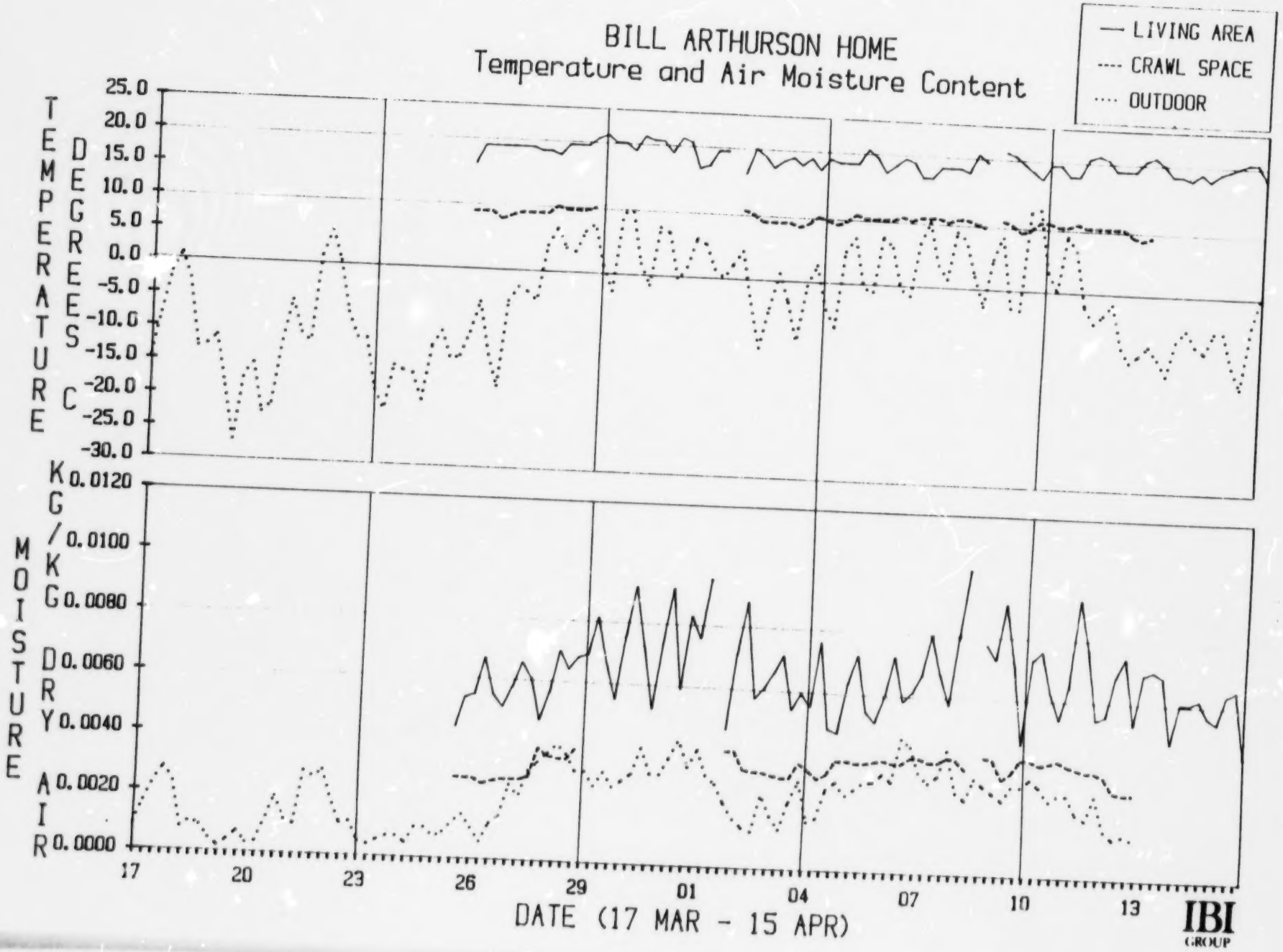
- polyethylene film added to floor and walls of crawl space;
- 0.25 mm (10 mil) polyethylene sealed to base of foundation wall insulation and to top of foundation wall;

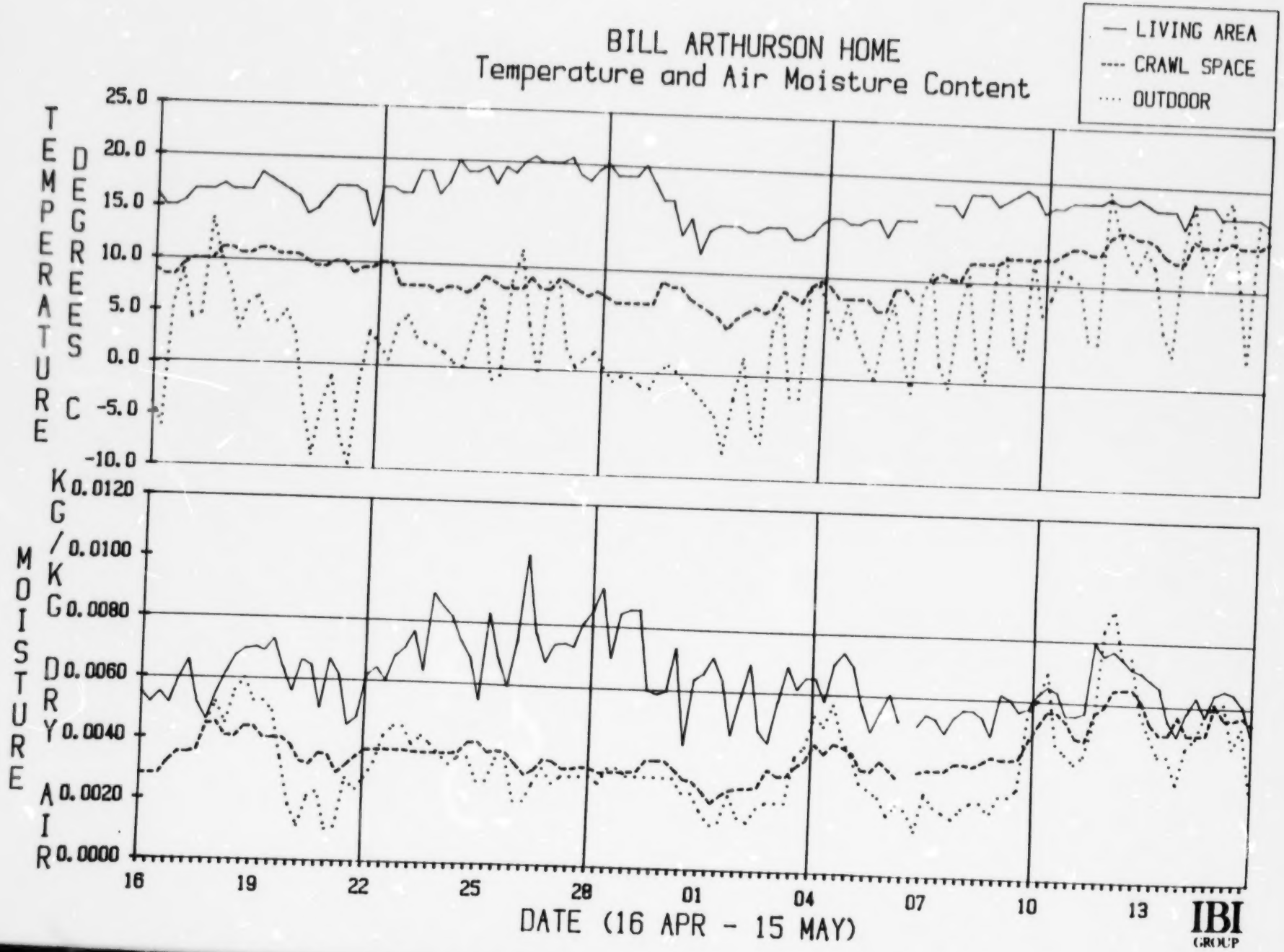
- o provided polyethylene lined cover for sump pump;
  - edge of sump pail lowered slightly below level of crawl space floor;
  - new polyethylene fastened to lip of sump pail;
  - plywood cover with polyethylene underside sealed around sump hose and electrical cord;
- o edges of crawl space access hatch weatherstripped;
- o sump hose extended 4 - 5 m from house;
- o provided removable insulated crawl space vent doors (RSI 4.4);
- o new sheet vinyl floor covering added in kitchen and living room. Floor covering applied on a K3 board base;
- o taped up and sealed off any duct joints and electrical wiring penetrations into the crawl space;
- o constructed and installed three storage pallets in the crawl space near the access hatch;
- o added a 1500 W Superior fan forced heater (15 amps) to the crawl space.

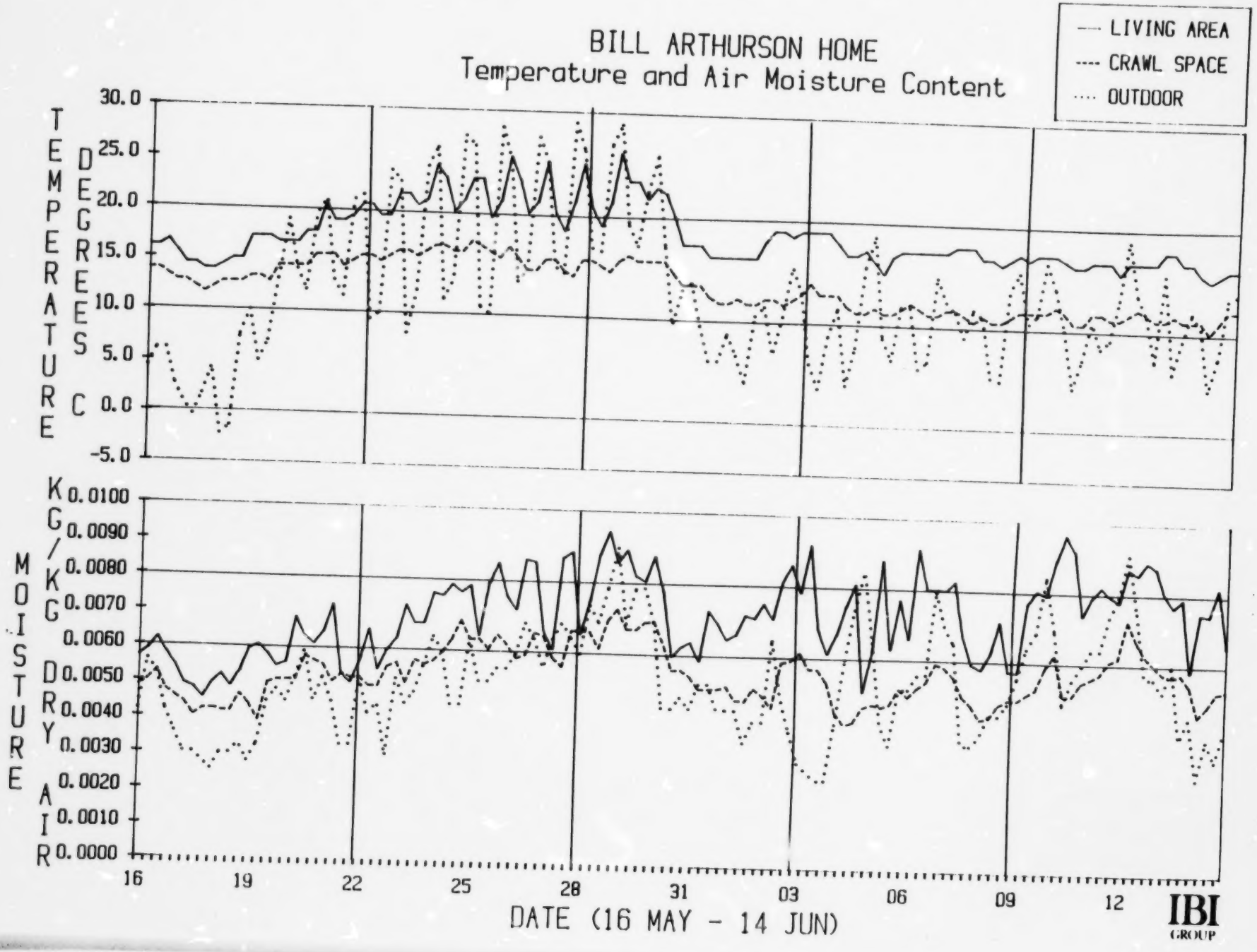
AIR MOISTURE CONTENT AND TEMPERATURE DATA CHARTS

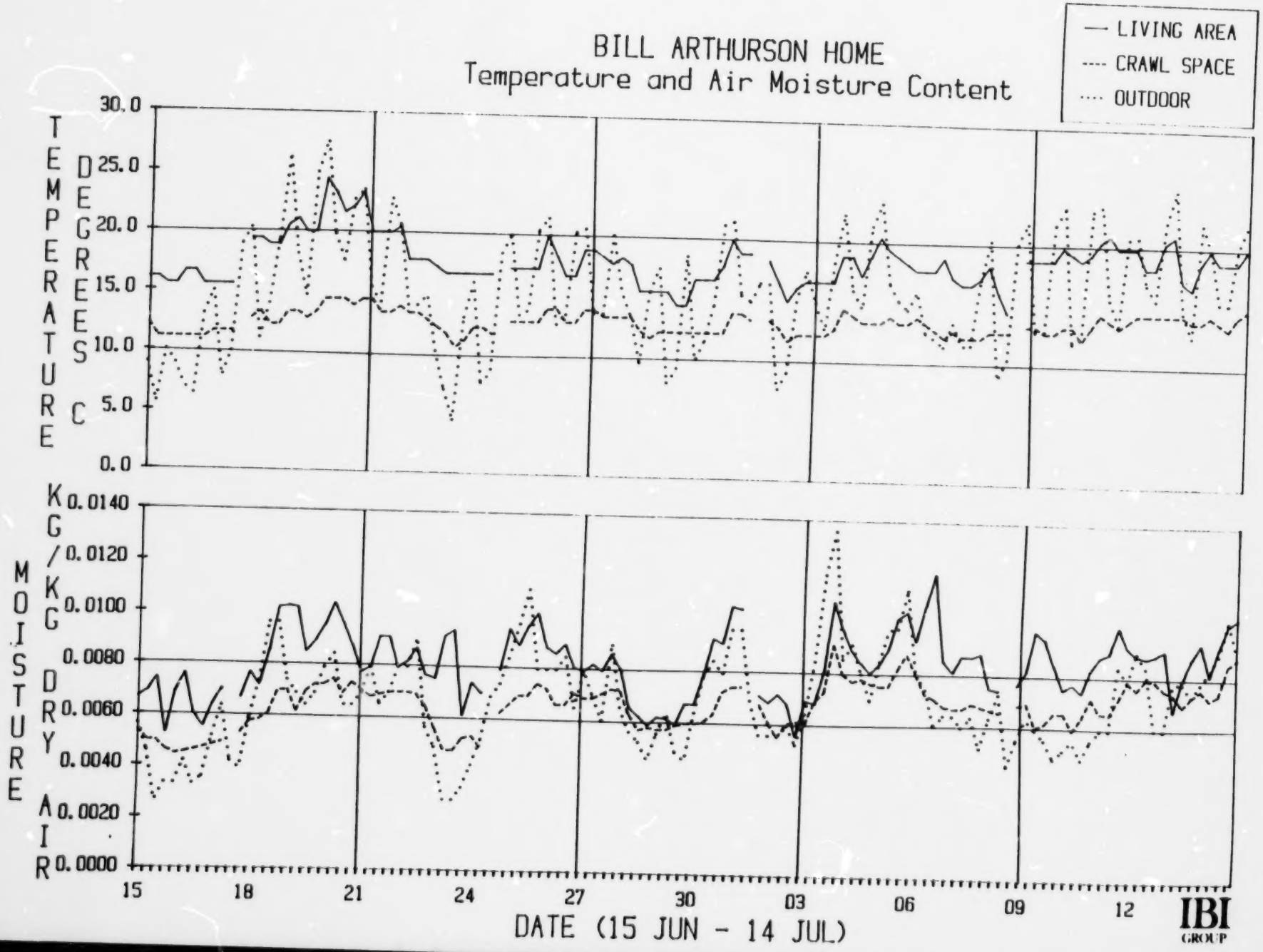

BILL ARTHURSON HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
MOISTURE KG/KG DRY AIR
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
15
18
21
24
27
30
02
05
08
11
14
DATE (15 JAN - 14 FEB)
IBI
GROUP


BILL ARTHURSON HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
MOISTURE AIR KG/KG DRY
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
15
18
21
24
27
02
05
08
11
14
DATE (15 FEB - 16 MAR)
IBI GROUP


BILL ARTHURSON HOME
Temperature and Air Moisture Content
— LIVING AREA
---- CRAWL SPACE
···· OUTDOOR
TEMPERATURE DEGREES C
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
MOISTURE KG/KG DRY AIR
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
17
20
23
26
29
01
04
07
10
13
DATE (17 MAR - 15 APR)
IBI
GROUP


BILL ARTHURSON HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
MOISTURE KG/KG DRY AIR
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
16
19
22
25
28
01
04
07
10
13
DATE (16 APR - 15 MAY)
IBI
GROUP


BILL ARTHURSON HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
MOISTURE AIR KG/KG DRY
0.0100
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
16
19
22
25
28
31
03
06
09
12
DATE (16 MAY - 14 JUN)
IBI
GROUP


BILL ARTHURSON HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
MOISTURE KG/KG DRY AIR
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
15
18
21
24
27
30
03
06
09
12
DATE (15 JUN - 14 JUL)
IBI GROUP

FLOOR SURFACE TEMPERATURE READINGS

ARTHURSON HOUSE

FLOOR SURFACE TEMPERATURE READINGS

DATE & TIME	CENTRE OF LIVING ROOM	CENTRE OF KITCHEN	MASTER BEDROOM	EAST BEDROOM	NORTH BEDROOM	WEST BEDROOM	BATHROOM	UTILITY ROOM
3 MAR 2:00 PM	20	19	18	20	18	19	-	18
6 MAR 1:20 PM	19	18	17	19	18	19	18	18
17 MAR 1:45 PM	21	21	18	18	19	18	19	20
25 MAR 10:35 AM	21	24	21	21	21	20	20	19
20 MAR 1:00 PM	18	19	18	18	19	18	19	18
1 APR 2:20 PM	22	22	20	22	20	19	19	20
8 APR 11:55 AM	23	22	18	19	20	19	20	20
15 APR 12 NOON	19	17	19	21	20	19	19	18
22 APR 10:25 AM	20	21	19	20	20	19	20	18
29 APR 11:10 AM	22	22	20	20	18	19	20	20
6 MAY 11:20 AM	18	18	16	15	15	17	16	17
13 MAY 2:00 PM	19	19	18	18	18	17	19	18
20 MAY 2:00 PM	23	25	21	22	22	21	23	22
27 MAY 1:10 PM	23	23	22	22	22	22	22	22
3 JUN 1:05 PM	18	19	17	17	17	17	18	18
10 JUN 1:30 PM	19	19	18	18	17	18	19	18

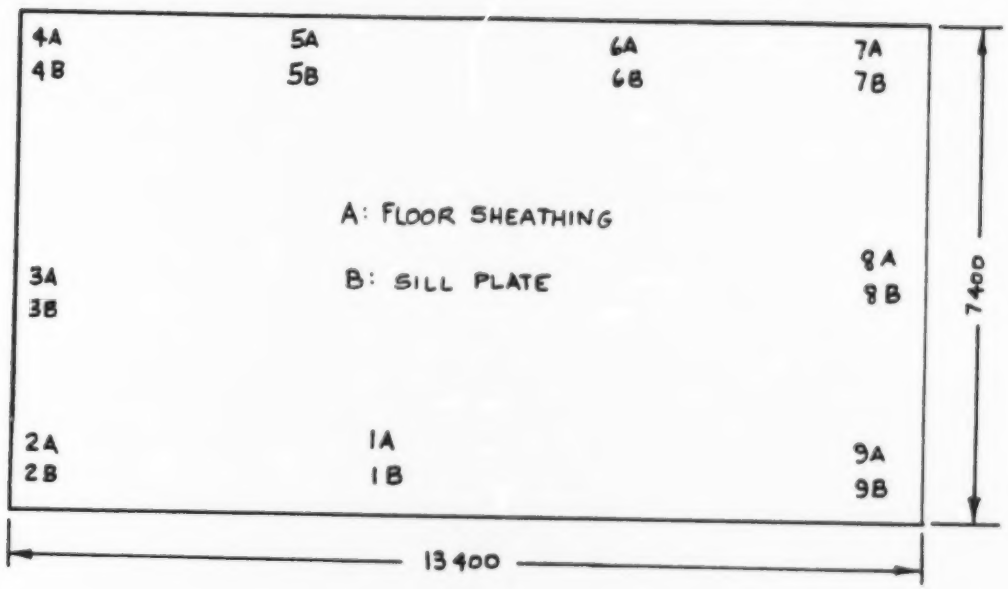
ARTHURSON HOUSE

FLOOR SURFACE TEMPERATURE READINGS

DATE & TIME	CENTRE OF LIVING ROOM	CENTRE OF KITCHEN	MASTER BEDROOM	EAST BEDROOM	NORTH BEDROOM	WEST BEDROOM	BATHROOM	UTILITY ROOM
17 JUN 11:55 AM	19	19	19	21	20	19	19	19
24 JUN 1:00 PM	18	19	18	18	19	18	18	18
1 JUL 2:30 PM	19	20	18	18	18	18	18	20
8 JUL 2:35 PM	21	23	19	19	19	19	20	20

WOOD MOISTURE CONTENT READINGS

Arthurson House
Wood Moisture Content Location Plan



FRONT
NORTH FACE

Arthurson House
Wood Moisture Content Readings

LOCATION \ DATE		JAN 17/86 (%)	MAR 25/86 (%)	MAY 3/86 (%)	JULY 19 '86 (%)
1	A	<9.0	10 5	13 5	20 5
	B	<9.0	<10.0	11 5	14 5
2	A	10.5	12.0	9 5	16 5
	B	14.0	14 0	15 0	15 5
3	A	16.0	12.0	9 5	15.0
	B	13.0	10.5	12 5	13 5
4	A	11.0	13 0	13 5	10 5
	B	13 0	11 0	12 5	13 0
5	A	*	18.0	15 0	18 0
	B	<9.0	<10 0	11 0	15 0
6	A	<9.0	<10.0	12 5	6 5
	B	10.0	<10.0	10 5	11.5
7	A	22.0	16 0	17 5	18.5
	B	14 0	13 0	15 0	15 5
8	A	9.0	10.5	11.5	15.0
	B	14.0	12.0	13 5	16 5

* SATURATED (≥30%)

Arthurson House
Wood Moisture Content Readings

LOCATION \ DATE		JAN 17/86 (%)	MAR 25/86 (%)	MAY 13/86 (%)	JULY 18/86 (%)
9	A	11.0	10.5	11 0	10. 5
	B	14 0	14.0	13 5	15 0

APPENDIX E: SAUNDERS HOUSE

Crawl Space Features and Retrofit Measures

Air Moisture Content and Temperature Data Charts

Floor Surface Temperature Readings

Wood Moisture Content Readings

CRAWL SPACE FEATURES AND RETROFIT MEASURES

SAUNDERS HOUSE

OCCUPANCY: 2 adults, 3 children

DWELLING CHARACTERISTICS:

- age: 7 years;
- type: bungalow;
- dimensions: 13.4 x 7.4 m;
- gross floor area: 99.2 m^2 (includes base of exterior wall).

CRAWL SPACE FEATURES (before retrofit):

- concrete foundation;
- clearance height: 890 mm;
- insulation: headers - batt insulation removed
  walls - 50 mm expanded polystyrene (type 2)
  footings - not insulated;
- site drainage: poor, seasonal flooding;
- polyethylene on crawl space floor covered with a thin layer of sand and partially peeled back;
- heating: no direct source, baseboard heater not plugged in;
- vents: boarded up but not sealed.

CRAWL SPACE OBSERVED PROBLEMS:

- polyethylene folded back in heavy water area and cut to provide a drainage trench;
- heavily exposed wet silty-clay below polyethylene film;
- headers thoroughly wetted;
- joists wet near headers;
- footing dripping wet;
- kitchen exhaust fan duct not connected.

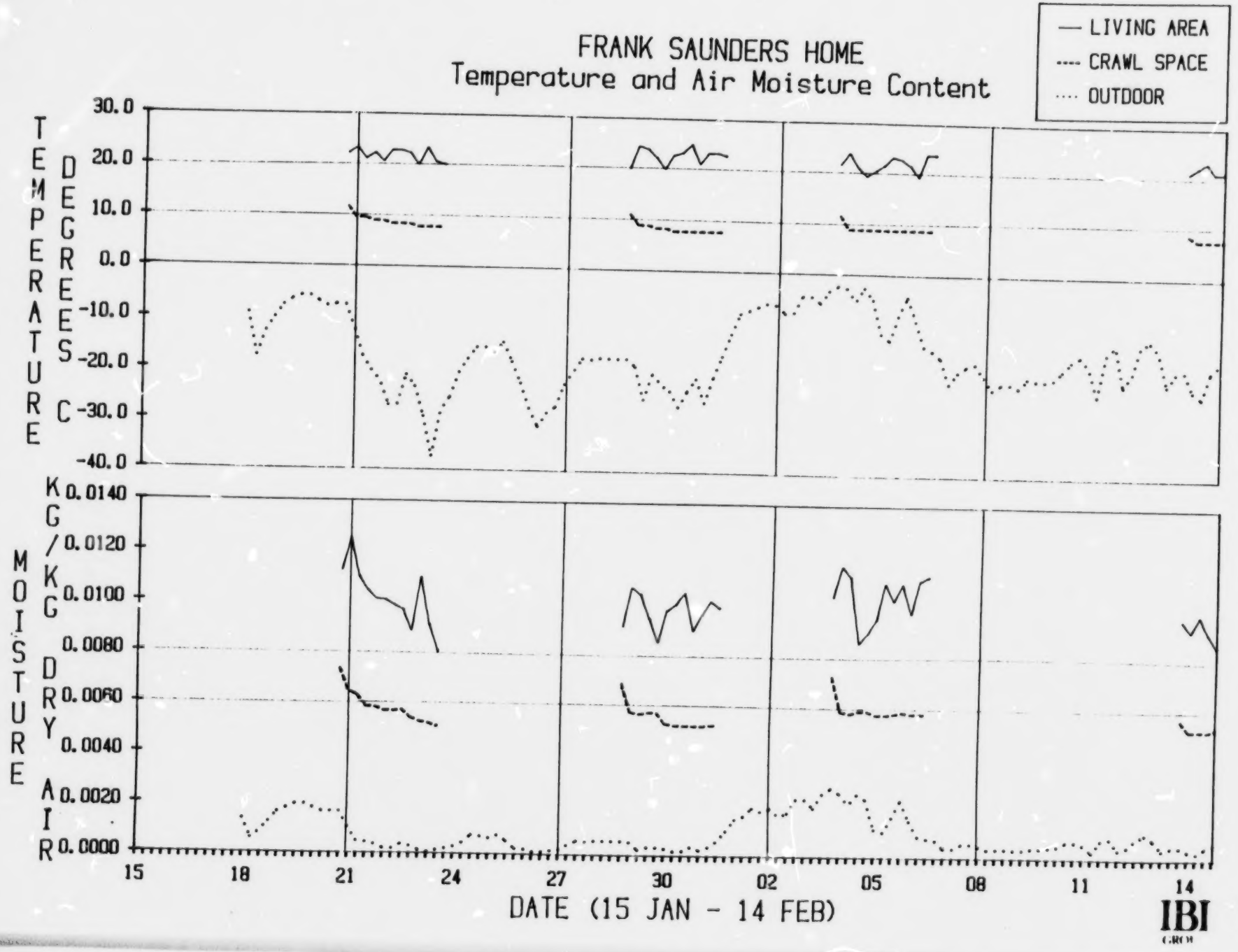
RETROFIT OBJECTIVE:

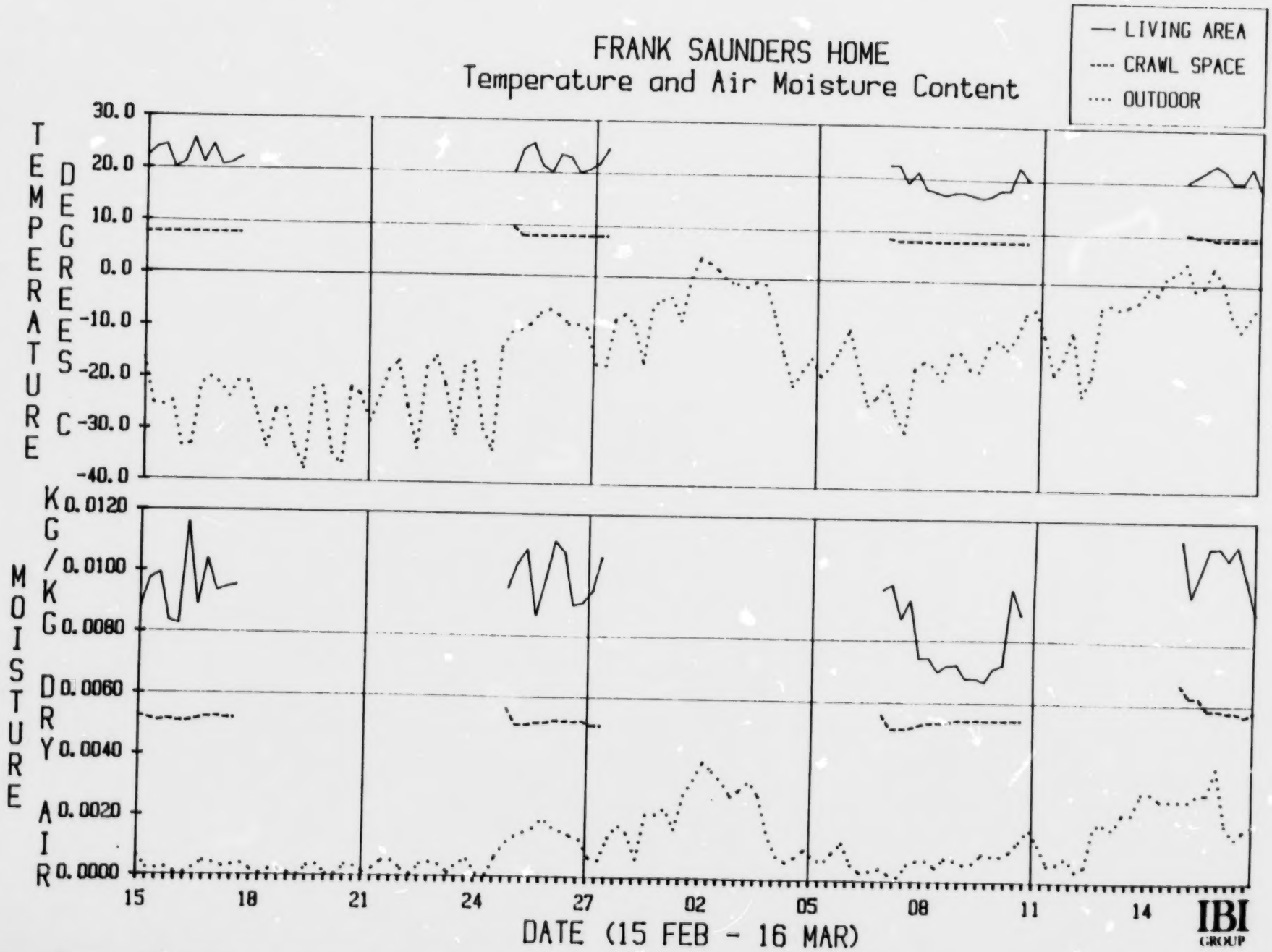
Demonstrate ability of living area floor to serve as moisture retarder.

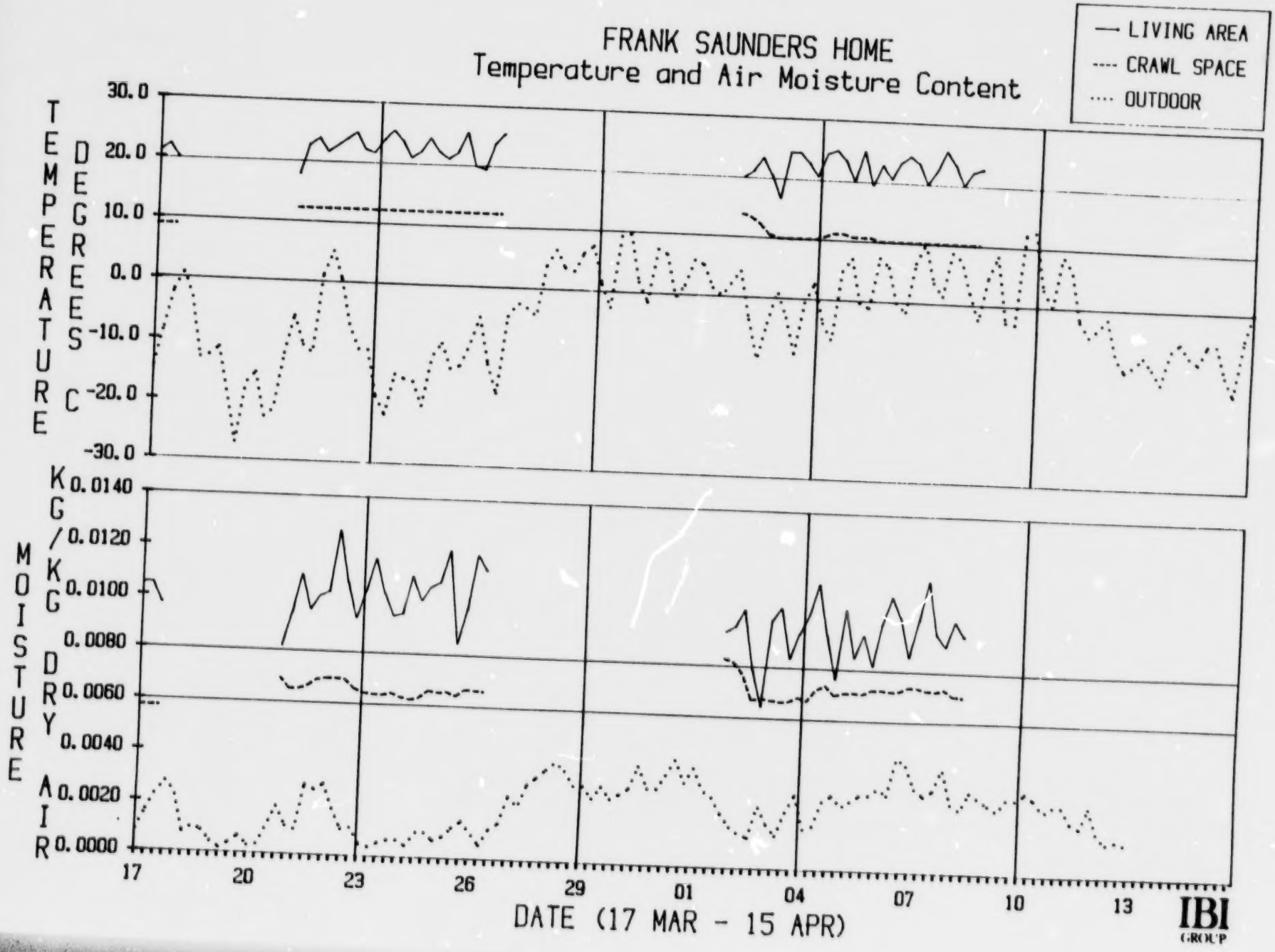
RETROFIT MEASURES:

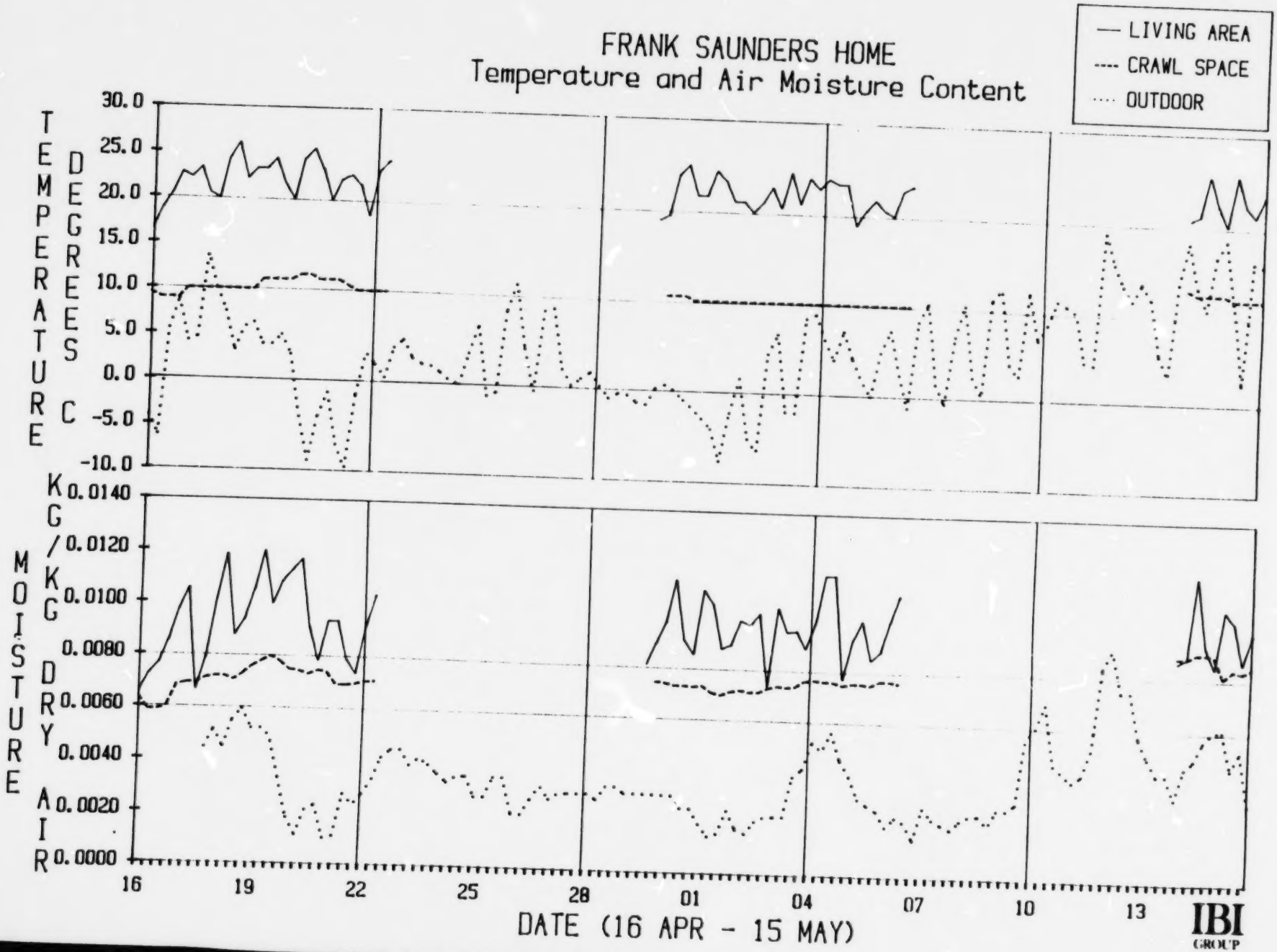
- o polyethylene film added to floor and walls of crawl space;
- o 0.25 mm (10 mil) polyethylene sealed to base of foundation wall insulation and to top of foundation wall;
- o provide a polyethylene lined cover for sump pump;
  - edge of sump pail lowered slightly below level of crawl space floor;
  - new polyethylene fastened to lip of sump pail;
  - plywood cover with polyethylene underside sealed around sump hose and electrical cord;
- o edges of crawl space access hatch weatherstripped;
- o extended sump pump hose away from house sufficiently to ensure water does not drain back into crawl space;
- o provided removable insulated crawl space vent doors (RSI 4.4);
- o taped up and sealed off any duct joints and electrical wiring penetrations into the crawl space;
- o constructed and installed three storage pallets in the crawl space near the access hatch;
- o added a 1500 W Superior fan forced heater (15 amps) to the crawl space.

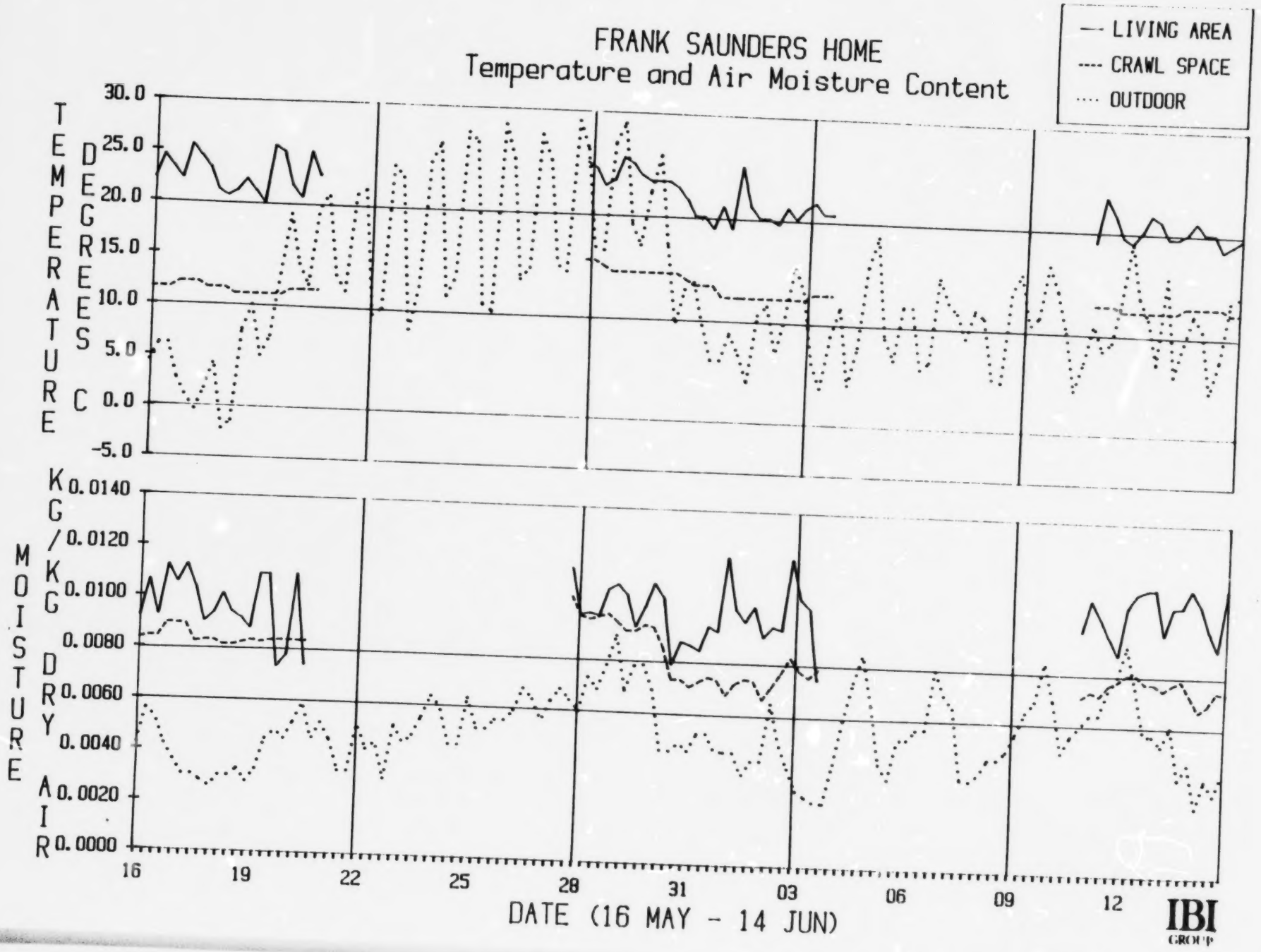
AIR MOISTURE CONTENT AND TEMPERATURE DATA CHARTS

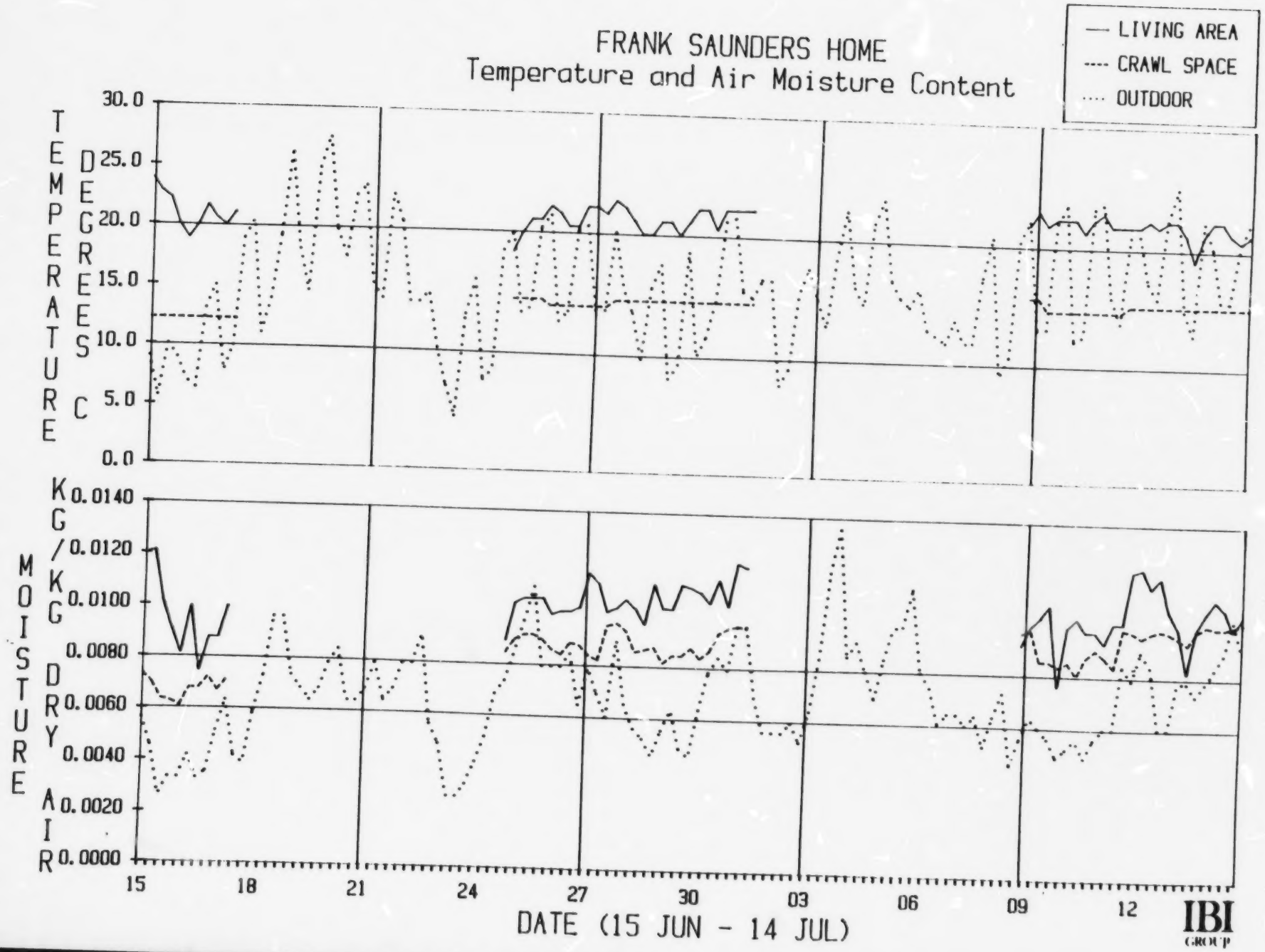

FRANK SAUNDERS HOME
Temperature and Air Moisture Content
— LIVING AREA
---- CRAWL SPACE
.... OUTDOOR
TEMPERATURE DEGREES C
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
MOISTURE KG/KG DRY AIR
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
15
18
21
24
27
30
02
05
08
11
14
DATE (15 JAN - 14 FEB)
IBI


FRANK SAUNDERS HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
MOISTURE KG/KG DRY AIR
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
15
18
21
24
27
02
05
08
11
14
DATE (15 FEB - 16 MAR)
IBI GROUP


FRANK SAUNDERS HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
MOISTURE KG/KG DRY AIR
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
17
20
23
26
29
01
04
07
10
13
DATE (17 MAR - 15 APR)
IBI GROUP


FRANK SAUNDERS HOME
Temperature and Air Moisture Content
— LIVING AREA
---- CRAWL SPACE
···· OUTDOOR
TEMPERATURE DEGREES C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
MOISTURE KG/KG DRY AIR
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
16
19
22
25
28
01
04
07
10
13
DATE (16 APR - 15 MAY)
IBI GROUP


FRANK SAUNDERS HOME
Temperature and Air Moisture Content
LIVING AREA
CRAWL SPACE
OUTDOOR
TEMPERATURE DEGREES C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
MOISTURE KG/KG DRY AIR
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
16
19
22
25
28
31
03
06
09
12
DATE (16 MAY - 14 JUN)
IBI GROUP


FRANK SAUNDERS HOME
Temperature and Air Moisture Content
— LIVING AREA
---- CRAWL SPACE
···· OUTDOOR
TEMPERATURE DEGREES C
30.0
25.0
20.0
15.0
10.0
5.0
0.0
MOISTURE KG/KG DRY AIR
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
15
18
21
24
27
30
03
06
09
12
DATE (15 JUN - 14 JUL)
IBI GROUP

FLOOR SURFACE TEMPERATURE READINGS

SAUNDERS HOUSE

FLOOR SURFACE TEMPERATURE READINGS

DATE & TIME	CENTRE OF LIVING ROOM	CENTRE OF KITCHEN	MASTER BEDROOM	WEST BEDROOM	NORTH BEDROOM	EAST BEDROOM	BATHROOM	UTILITY ROOM
27 FEB 11:20 AM	20	20	19	19	19	21	-	21
6 MAR 1:45 PM	18	17	17	17	17	17	17	17
14 MAR 1:15 PM	18	18	18	18	18	18	18	18
17 MAR 1:20 PM	18	17	17	17	17	17	17	17
20 MAR 1:30 PM	20	19	19	19	19	19	19	19
1 APR 2:30 PM	20	20	19	19	20	19	19	19
8 APR 12 NOON	17	16	17	17	17	17	17	17
15 APR 11:40 AM	18	16	19	19	19	19	19	20
22 APR 10:40 AM	18	19	18	18	18	18	17	18
25 APR 2:35 PM	19	19	19	18	18	19	19	19
29 APR 12 NOON	18	17	19	19	19	20	19	19
6 MAY 11:40 AM	18	16	20	20	20	20	19	21
13 MAY 1:40 PM	20	19	20	20	19	20	20	19
20 MAY 2:10 PM	22	23	21	20	20	21	21	21
27 MAY 1:00 PM	24	23	21	21	21	22	22	22
3 JUN 1:15 PM	19	19	19	18	18	19	19	18

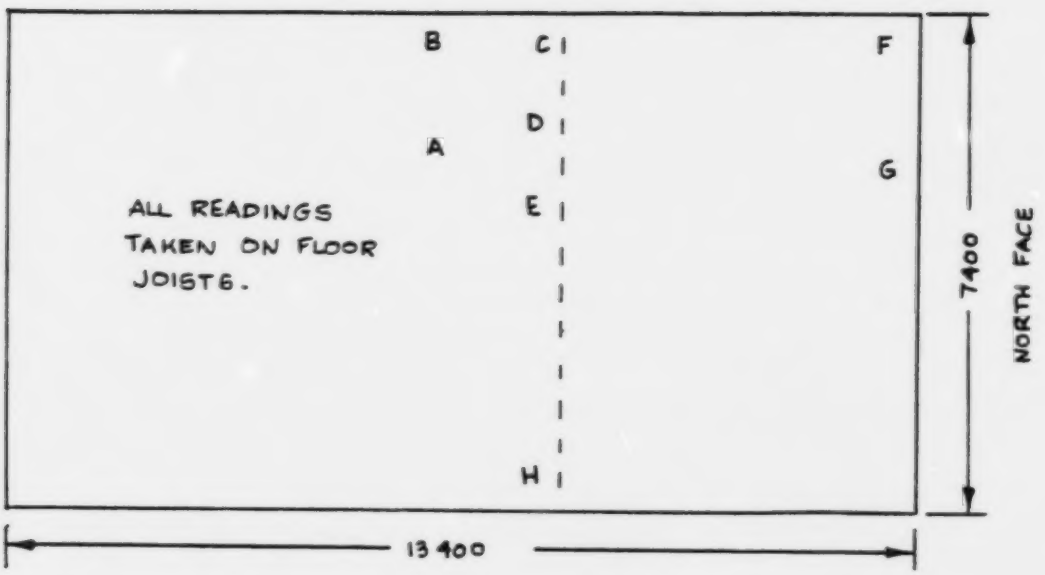
SAUNDERS HOUSE

FLOOR SURFACE TEMPERATURE READINGS

DATE & TIME	CENTRE OF LIVING ROOM	CENTRE OF KITCHEN	MASTER BEDROOM	WEST BEDROOM	NORTH BEDROOM	EAST BEDROOM	BATHROOM	UTILITY ROOM
10 JUN 1:20 PM	20	19	19	19	18	19	19	19
17 JUN 11:40 AM	23	23	21	21	20	21	22	22
24 JUN 12:50 PM	20	19	18	18	20	18	19	19
1 JUL 2:35 PM	22	22	22	21	21	22	22	22
8 JUL 2:30 PM	23	22	21	20	20	20	22	21

WOOD MOISTURE CONTENT READINGS

Saunders House
Wood Moisture Content Location Plan



Saunders House
Wood Moisture Content Readings

DATE / LOCATION	JAN 19/93 (%)	MAR 25/93 (%)	MAY 13/93 (%)	JULY 19/93 (%)
A	23.0	15.5	18.0	20.5
B	23.0	15.5	19.5	20.5
C	23.0	19.0	20.0	21.0
D	20.0	16.0	18.0	20.5
E	18.5	15.5	17.0	17.0
F	*	27.0	29.0	29.0
G	21.5	18.5	20.0	22.0
H	21.0	18.0	20.0	20.5

* SATURATED (≥30%)

APPENDIX F: RETROFIT DETAILS

RETROFIT DETAILS

This appendix contains the retrofit details used in the four homes selected for retrofit.

Application of Sealants

- Tremco Acoustical Sealant was used in sealing joints in polyethylene:
- joints were overlapped 150 mm (6 in.) and continuously sealed everywhere;
- before applying sealant, any dirt or loose particles were removed from the contact surface;

Installation of Polyethylene

- the polyethylene on the crawl space floor was installed in such a way so as not to become unsealed when applying pressure on the crawl space floor. There should be no danger of breaking a sealed joint or seam when walking on any part of the crawl space floor;
- polyethylene installed along the crawl space walls was sealed around the vent holes and installed in such as way so as not to be damaged during insertion or extraction of the insulated vent door.

Removable Insulated Vent Doors

- the removable insulated vent doors were fabricated for the homeowner to install from the outside of the house;
- the doors are fitted snug with the use of vinyl sweeps;
- there are four vents per dwelling.

Sump Pump Covers

- the plywood sump pump cover is weatherstripped around the neck of the sump pump and the sump hose (see Exhibit F2A), or the electrical cord and the sump hose as applicable;
- the two pieces of the sump pump cover remain rigid with assistance of guide rails;
- the cover is weighted down with rocks or equivalent.

Crawl Space Access Hatch Weatherstripping

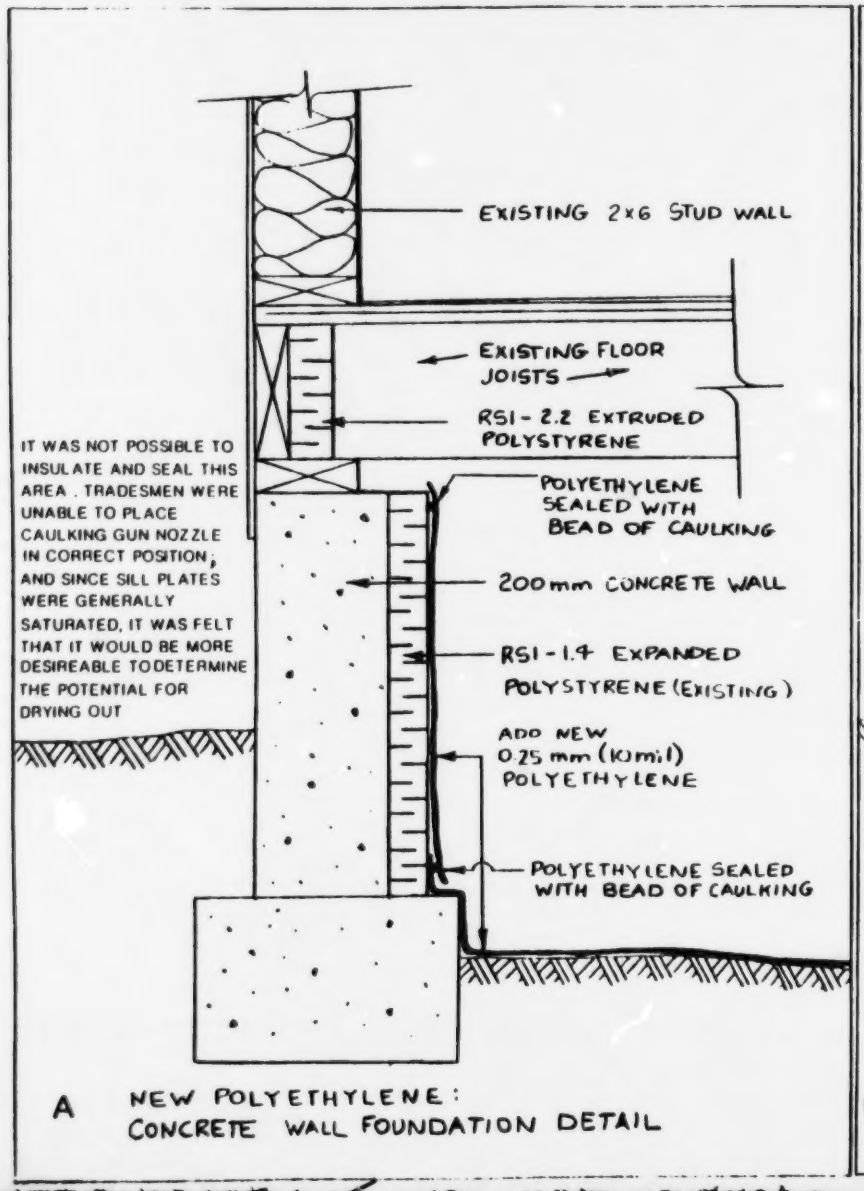
- the weatherstripping around the hatch cover perimeter (see Exhibit F3A) is of rolled foam;
- the weatherstripping provided a continuous seal around the crawl space access hatch.

Crawl Space Pallets

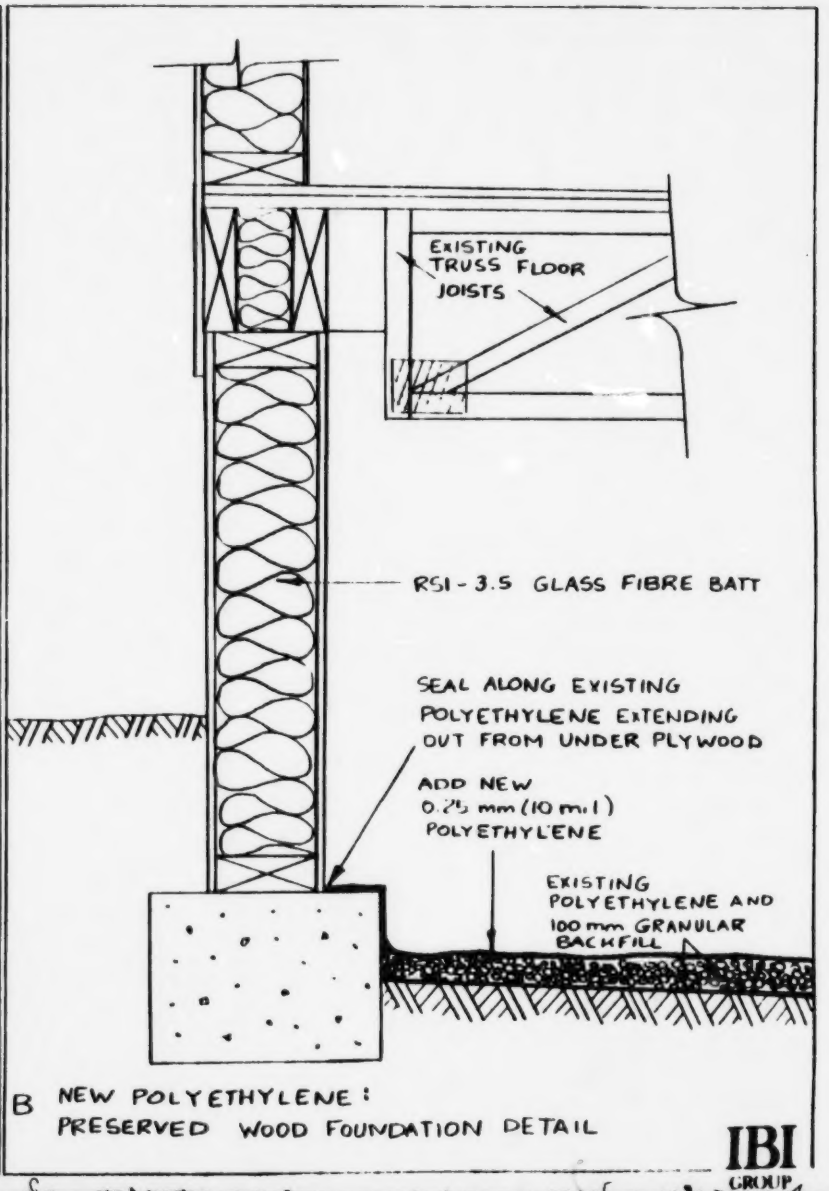
- pallets were assembled on existing crawl space floor before new polyethylene was fully applied to floor.
- a total of 12 pallets were constructed.

EXHIBIT F1 Norway House: Retrofit Details

NOT TO SCALE


EXISTING 2x6 STUD WALL
EXISTING FLOOR JOISTS
RSI - 2.2 EXTRUDED POLYSTYRENE
IT WAS NOT POSSIBLE TO INSULATE AND SEAL THIS AREA . TRADESMEN WERE UNABLE TO PLACE CAULKING GUN NOZZLE IN CORRECT POSITION; AND SINCE SILL PLATES WERE GENERALLY SATURATED, IT WAS FELT THAT IT WOULD BE MORE DESIREABLE TO DETERMINE THE POTENTIAL FOR DRYING OUT
POLYETHYLENE SEALED WITH BEAD OF CAULKING
200mm CONCRETE WALL
RSI - 1.4 EXPANDED POLYSTYRENE (EXISTING)
ADD NEW 0.25 mm (10 mil) POLYETHYLENE
POLYETHYLENE SEALED WITH BEAD OF CAULKING

A NEW POLYETHYLENE: CONCRETE WALL FOUNDATION DETAIL

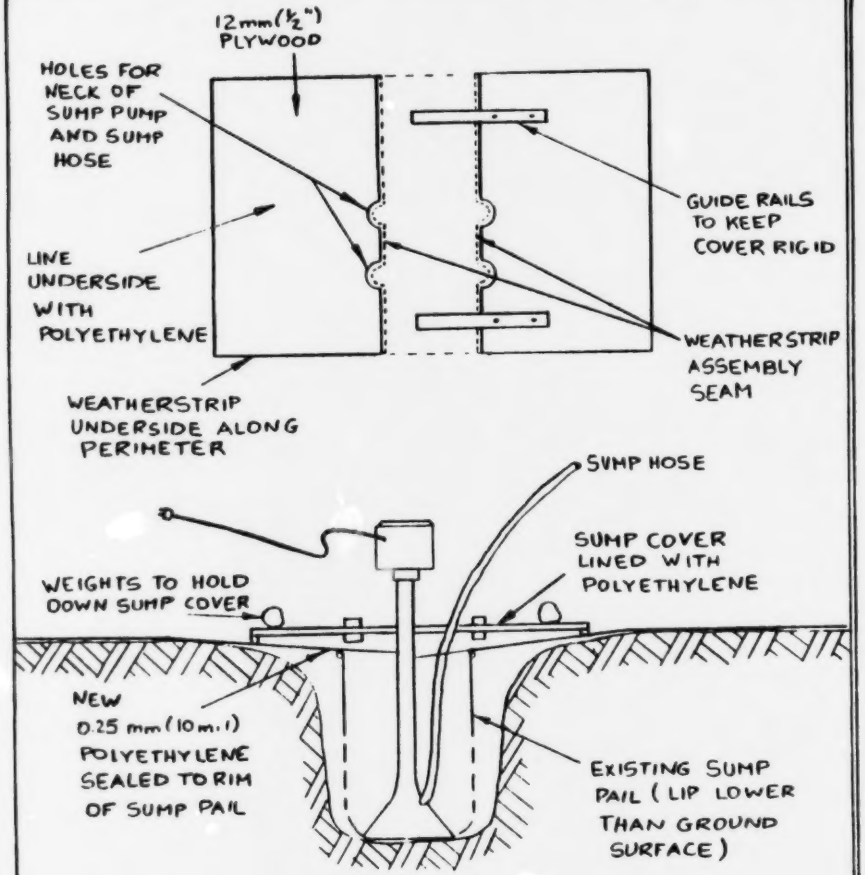

EXISTING TRUSS FLOOR JOISTS
RSI - 3.5 GLASS FIBRE BATT
SEAL ALONG EXISTING POLYETHYLENE EXTENDING OUT FROM UNDER PLYWOOD
ADD NEW 0.25 mm (10 mil) POLYETHYLENE
EXISTING POLYETHYLENE AND 100 mm GRANULAR BACKFILL

B NEW POLYETHYLENE: PRESERVED WOOD FOUNDATION DETAIL

IBI GROUP

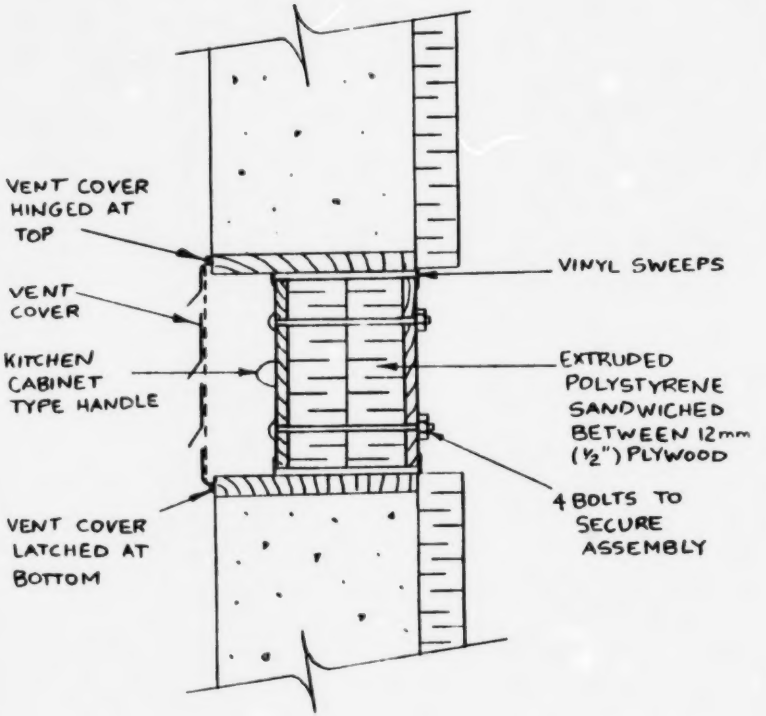
EXHIBIT F2 Norway House: Retrofit Details

NOT TO SCALE


12mm(½") PLYWOOD
HOLES FOR NECK OF SUMP PUMP AND SUMP HOSE
GUIDE RAILS TO KEEP COVER RIGID
LINE UNDERSIDE WITH POLYETHYLENE
WEATHERSTRIP ASSEMBLY SEAM
WEATHERSTRIP UNDERSIDE ALONG PERIMETER
SUMP HOSE
SUMP COVER LINED WITH POLYETHYLENE
WEIGHTS TO HOLD DOWN SUMP COVER
NEW 0.25 mm (10 m.l) POLYETHYLENE SEALED TO RIM OF SUMP PAIL
EXISTING SUMP PAIL (LIP LOWER THAN GROUND SURFACE)

NOTE: SOME SUMP PUMPS ARE SHORTER THAN THE PAIL THEREFORE THE ELECTRICAL CORD PASSES THROUGH THE COVER INSTEAD OF THE PUMP NECK

A SUMP PUMP COVER DETAIL

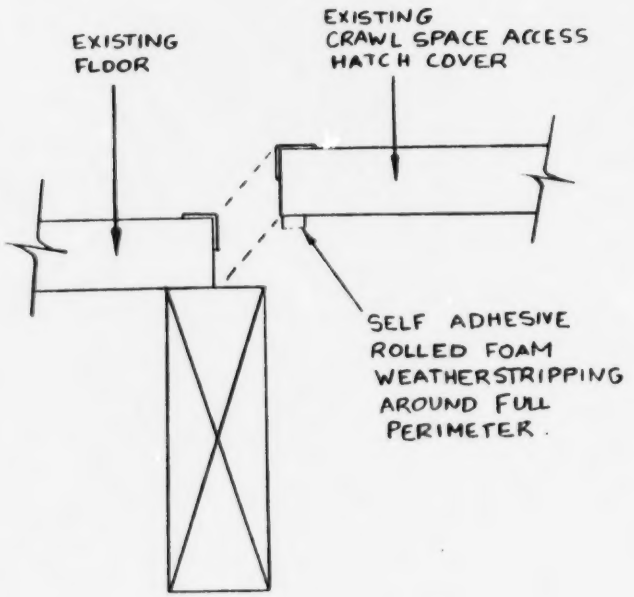

VENT COVER HINGED AT TOP
VINYL SWEEPS
VENT COVER
KITCHEN CABINET TYPE HANDLE
EXTRUDED POLYSTYRENE SANDWICHED BETWEEN 12mm (½") PLYWOOD
4 BOLTS TO SECURE ASSEMBLY
VENT COVER LATCHED AT BOTTOM

B REMOVABLE INSULATED VENT DOOR DETAIL

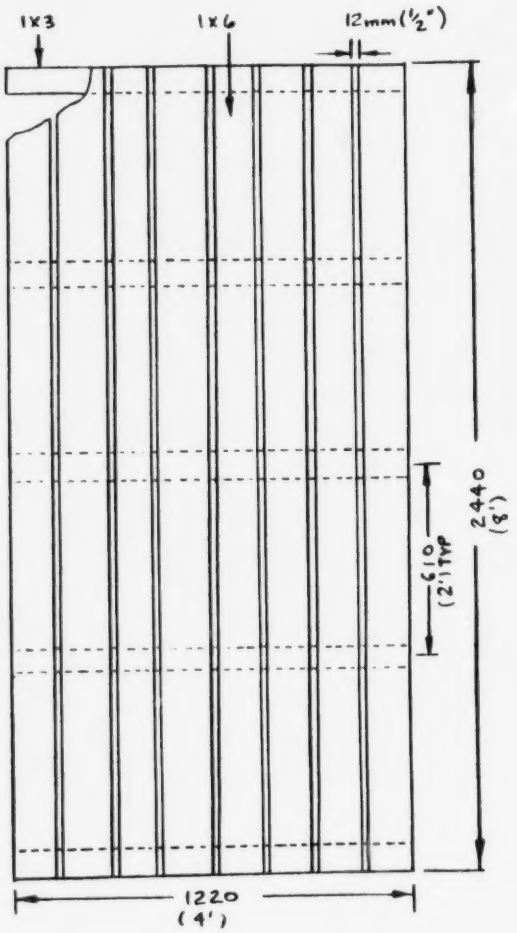
IBI GROUP

EXHIBIT F3 Norway House: Retrofit Details

NOT TO SCALE


EXISTING FLOOR
EXISTING CRAWL SPACE ACCESS HATCH COVER
SELF ADHESIVE ROLLED FOAM WEATHERSTRIPPING AROUND FULL PERIMETER.

A WEATHERSTRIPPING: CRAWL SPACE ACCESS HATCH DETAIL



B CRAWL SPACE PALLET DETAIL

IBI GROUP

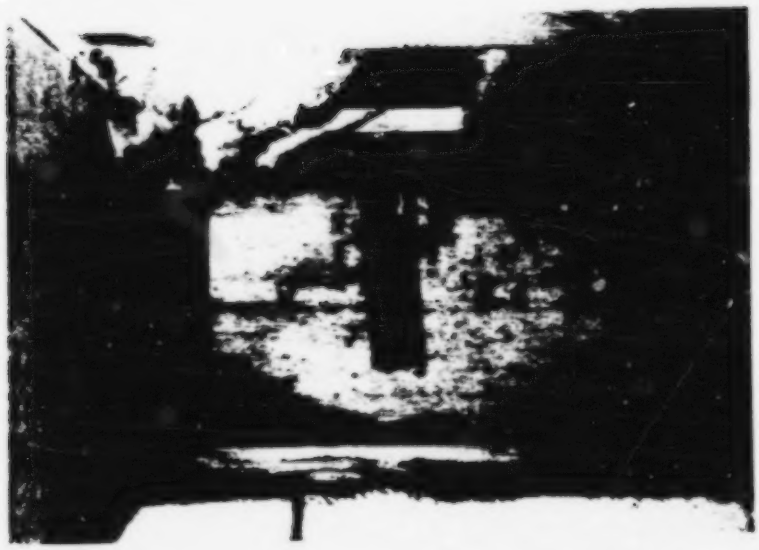
APPENDIX G: PHOTOGRAPHS OF ILLUSTRATIVE CONDITIONS

South elevation, front of house
(Laugner House)

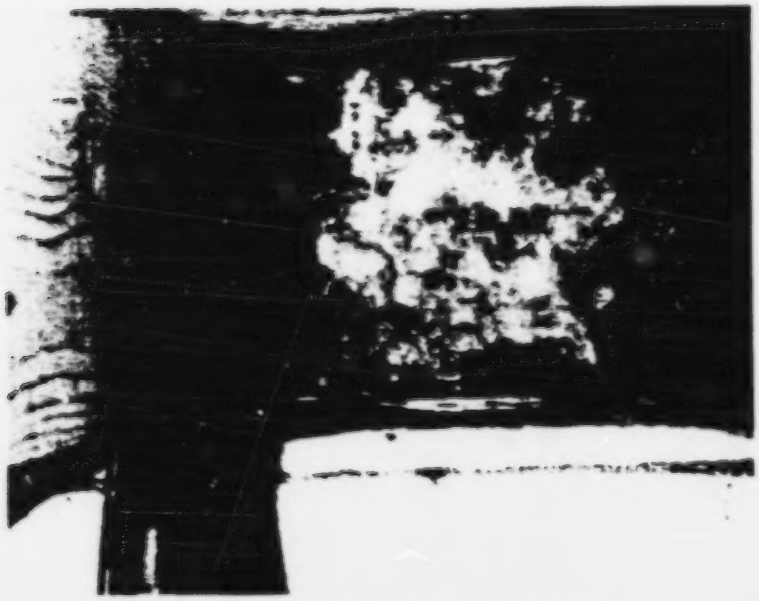
West elevation, back of house
(Saunders House)

Conditions of polyethylene (6 mil) on
crawl space floor before retrofit (Arthurson House)

Heavily stained header above wall
insulation before retrofit (Saunders House)



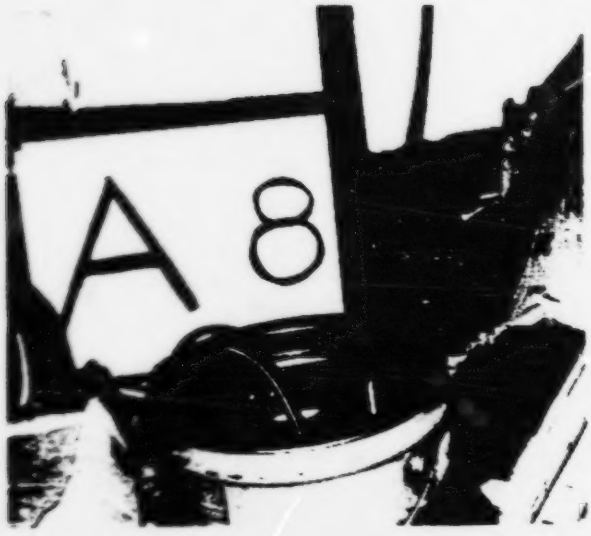
Heavily water stained sill plate, header and floor sheathing. Existing bathroom plumbing also shown (Laugner House)



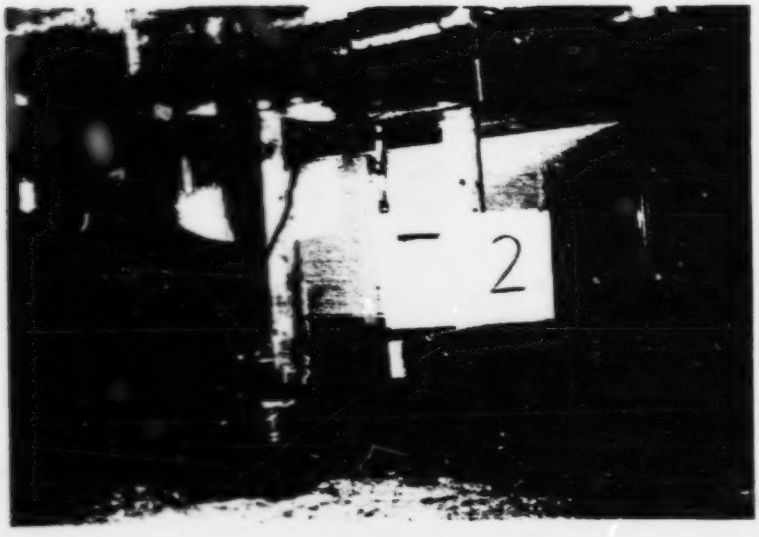
Pieces of batt insulation frozen onto header and accumulations of ice beside sill plate (Laugner House)

Moisture stains in corner of PWF (Tait House)

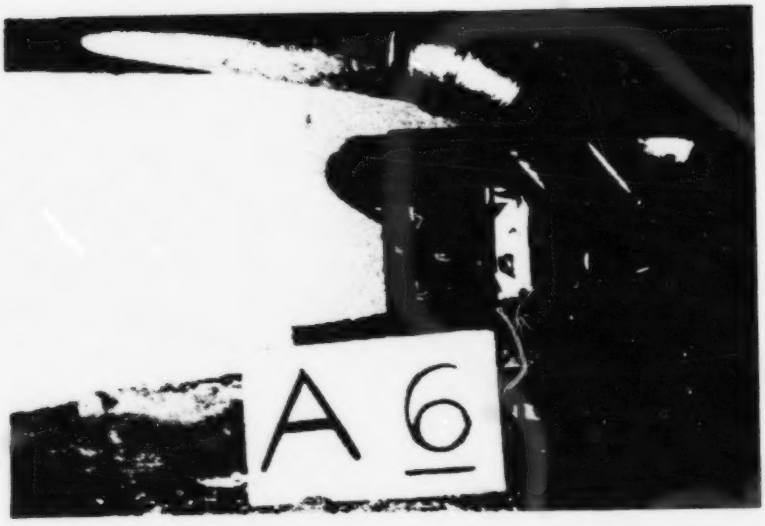
Moisture stains and mould growth in corner on underside of floor sheathing (Tait House)



Typical sump pump installation before retrofit
(Arthurson House)

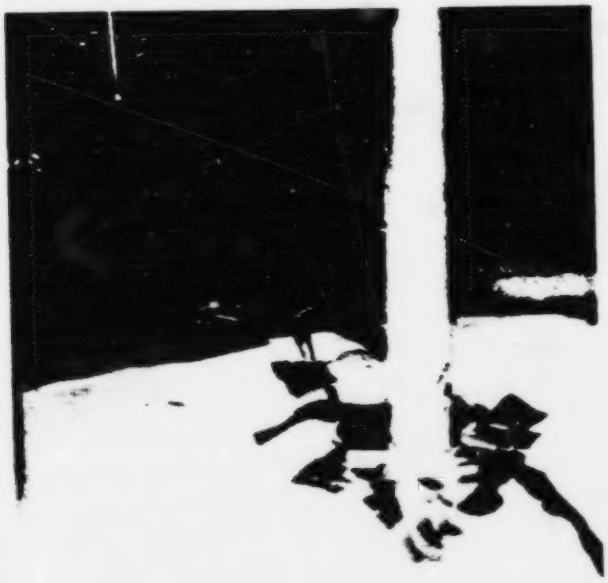


Forced air furnace and ducting showing sump pump and weeping tiles before retrofit. Clearance height 1,120 mm (Tait House)

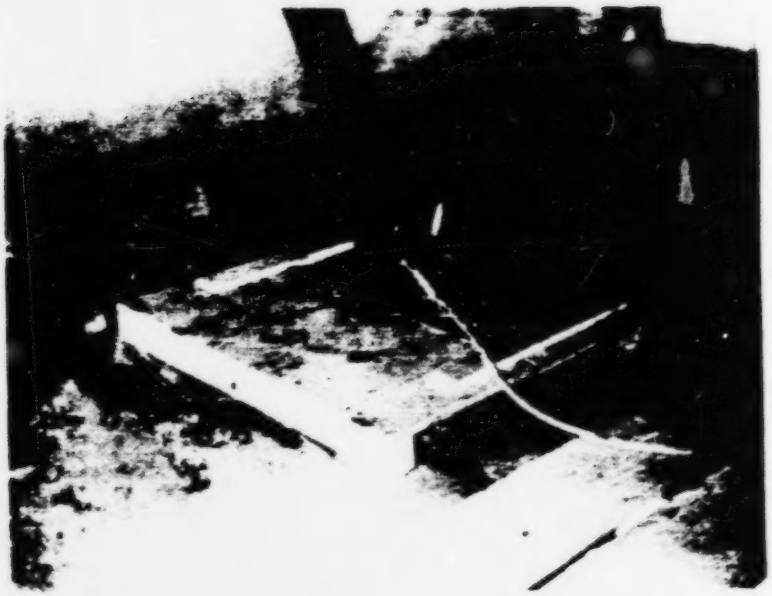


Typical kitchen exhaust fan motor and ducting sealed so as to prevent mixing with crawl space air. (Arthurson House)

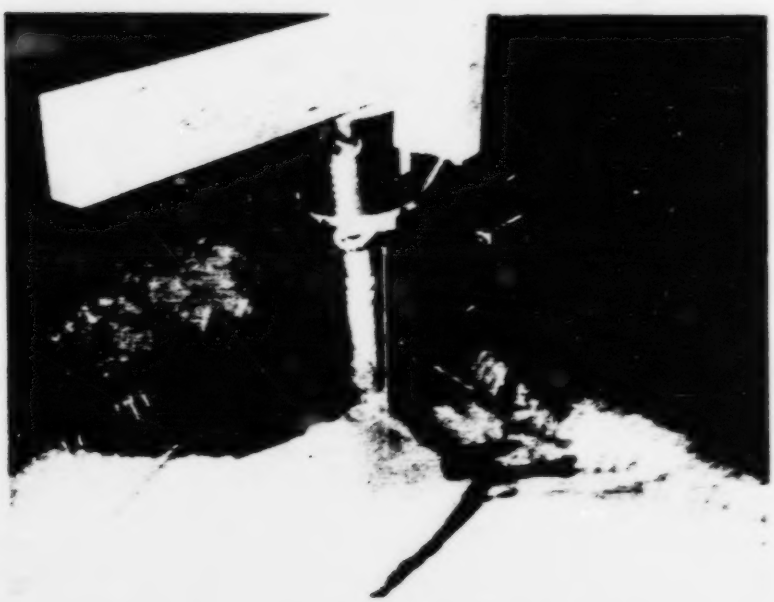
New polyethylene (10 mil) on crawl space
floor and walls after retrofit (Arthurson House)



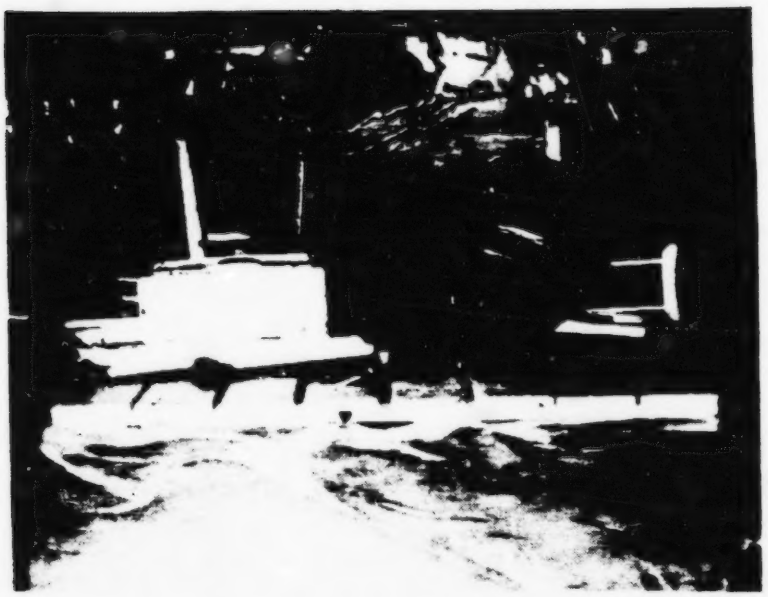
New polyethylene (10 mil) sealed around main floor supporting
posts and overlapped on crawl space floor (Arthurson House)



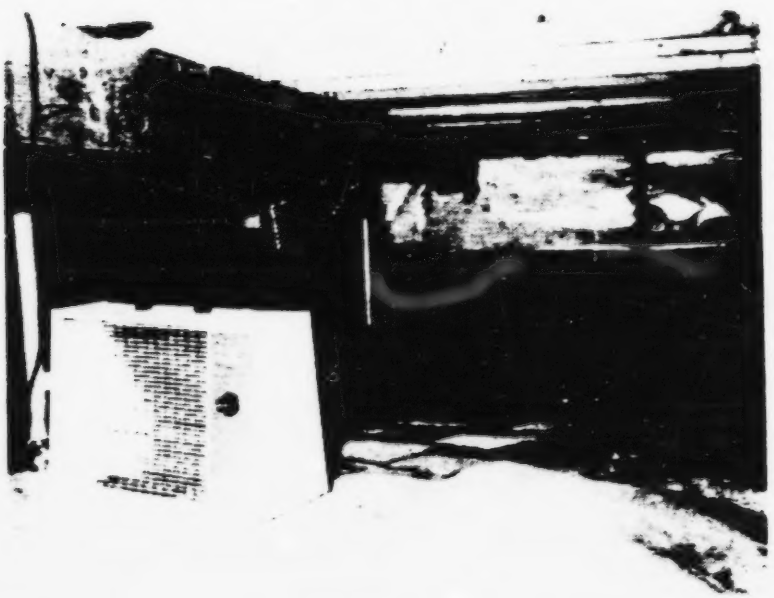
Typical sump pump installation with
cover after retrofit (Laugher House)



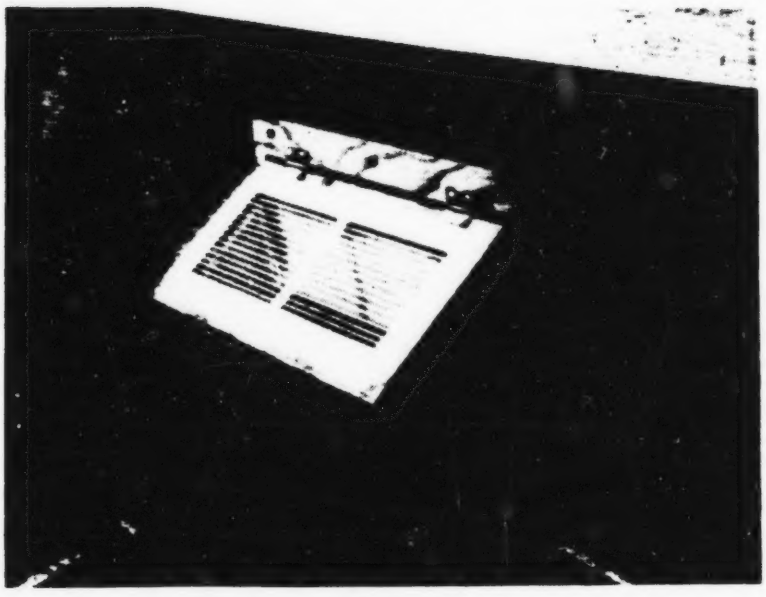
Sump pump installation with weeping tiles
lowered after retrofit (Tait House)



Newly constructed crawl space storage pallet in use (Arthurson House)



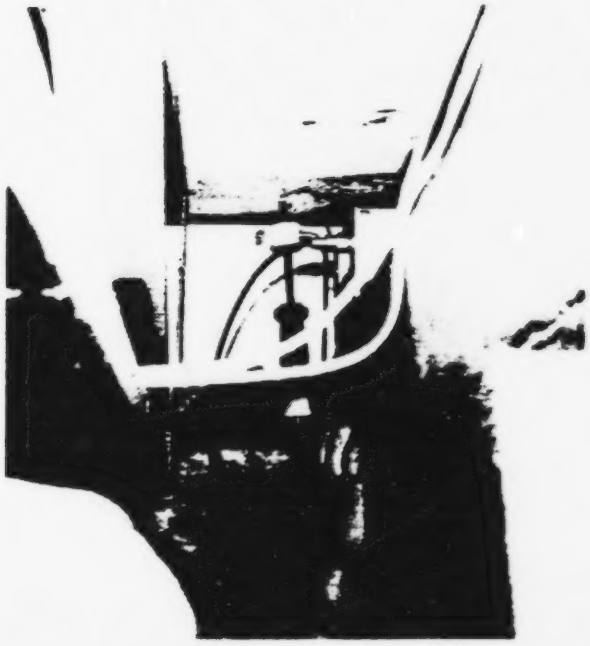
New 1500 W Superior Fan Forced electric heater. Crawl space clearance height 760 mm (Laugher House)



Newly installed hinged vent
cover on PWF wall (Tait House)

Spring flooding as seen in two crawl spaces
(Laugher House)

Honeywell 612 Hygrometer installed
in one of the crawl spaces.



Delmhorst G-30 Wood Moisture Detector reading
floor sheathing moisture content.